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THESIS

MARINE THIRTY-YEAR PLAN

by

Jacob C. Enholm

March 2002

Co-Advisors:	Kevin Wood
	Samuel E. Buttrey
Second Reader:	Gregory K. Mislick

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The U.S. Marine Corps is in need of a unified enlisted manpower model to guide the recruiting, training, promoting and discharging of an enlisted force of over 153,000 Marines. This thesis develops a set of linear programs (LPs) for this purpose. Each LP optimizes the estimated manpower structure within an occupational field by varying the number of recruits, promotions, and lateral moves over a 30-year time horizon, at a yearly level of detail. The goal is to meet annual force-level targets specified by Headquarters Marine Corps for cohorts defined by occupational specialty, and rank. Estimated attrition rates are key inputs; these are based on Kaplan-Meier estimators for "survival probabilities" computed from Marine Corps data covering 1990-2000. Current force strength data, also required by the LPs, is derived from the Marine Corps database. Average LP solving time is less than thirty minutes on a Pentium IV 2 Ghz personal computer, using the GAMS modeling system and the CPLEX LP solver.

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MARINE THIRTY-YEAR PLAN

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Captain, United States Marine Corps
B.S., University of Arizona, 1994

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

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ABSTRACT

The U.S. Marine Corps is in need of a unified enlisted manpower model to guide the recruiting, training, promoting and discharging of an enlisted force of over 153,000 Marines. This thesis develops a set of linear programs (LPs) for this purpose. Each LP optimizes the estimated manpower structure within an occupational field by varying the number of recruits, promotions, and lateral moves over a 30-year time horizon, at a yearly level of detail. The goal is to meet annual force-level targets specified by Headquarters Marine Corps for cohorts defined by occupational specialty and rank. Estimated attrition rates are key inputs; these are based on Kaplan-Meier estimators for "survival probabilities" computed from Marine Corps data covering 1990-2000. Current force strength data, also required by the LPs, is derived from the Marine Corps database. Average LP solving time is less than thirty minutes on a Pentium IV 2 Ghz personal computer, using the GAMS modeling system and the CPLEX LP solver.

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LIST OF ACRONYMS

1stSgt	First Sergeant/Administrative E-8
CNA	Center for Naval Analyses
Cpl	Corporal/E-4
EAM	Enlisted Accessions Model
fspggar	Force Structure Planning Group Grade-Adjusted Recapitalization
FTAP	First Term Alignment Plan
GAMS	General Algebraic Modeling System
GySgt	Gunnery Sergeant/E-7
HQMC	Headquarters Marine Corps
LCpl	Lance Corporal/E-3
LP	Linear Program
M&RA	Manpower and Reserve Affairs
MCBUL	Marine Corps Bulletin
MCO	Marine Corps Order
MGySgt	Master Gunnery Sergeant/E-9
MOS	Military Occupational Specialty
MSgt	Master Sergeant/E-8
MTYP	Marine Thirty-Year Plan
Pfc	Private First Class/E-2
Pvt	Private/E-1
Sgt	Sergeant/E-5
SgtMaj	Sergeant Major/Administrative E-9
SNCO	Staff Noncommissioned Officer (E-6 or above)
SSgt	Staff Sergeant/E-6
STAP	Subsequent Term Alignment Plan
TIG	Time In Grade
YOS	Years of Service

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EXECUTIVE SUMMARY

The U.S. Marine Corps is in need of an integrated enlisted manpower model to guide the recruiting, training, promoting and discharging of an enlisted force of over 153,000 Marines. There are three separate models currently in use which cover three different contractual periods of a Marine's potential thirty-year career. These models are not integrated. This thesis develops a linear program (LP) that covers all three periods simultaneously, for Marine cohorts in a single occupational field. (A cohort is a group with the same rank, time in service, time in grade, and military occupational specialty (MOS); an occupational field is a group with similar MOSs)

The three current models are: the Enlisted Accessions Model (EAM) which estimates initial numbers required to keep Marine cohorts at targeted levels through their initial contracts; the First Term Alignment Plan (FTAP) which models the demand for Marines who are reenlisting, and covers the second contract period; and the Second Term Alignment Plan (STAP) which was only recently added to the system (in November 2001). STAP uses the same methodology as FTAP but deals with Marines who reenlist a second time and covers career years eight through 20. Presently cohort level changes in EAM must be manually entered into FTAP, and changes in FTAP must be manually entered into STAP. Cohorts in all of these models are aggregated by rank, and cannot be used to plan promotions. The result is an overall planning system where accessions are not coordinated with promotions; attrition is not properly tracked; promotions are filled as available; and there is wide year-to-year variation in the number of promotions.

This thesis presents the Marine Thirty-Year Plan (MTYP), a linear program (LP) that unifies planning by tying cohorts together over a thirty-year time horizon. Separate LPs are solved for each occupational field because there are only modest connections between the various fields. MTYP may be viewed as a multi-period, multi-commodity inventory model.

The effects of attrition are accounted for at discrete-year intervals. These effects are calculated by multiplying each cohort strength variable by an attrition estimator. The estimator chosen for MTYP is based on the Kaplan-Meier survivor estimators, which are calculated for each MOS using data from 1990-2000. Estimates for new MOSs created

during that time period, for which insufficient data exists, are calculated from substitute MOSs having similar characteristics. Punitive rank reductions that are not explicitly noted in the data must be accounted for in computing attrition estimates. Some of these reductions can be identified as anomalous discharge data, and adjustments are automatically made for them.

Each MTYP LP is initialized with data taken from current Marine Corps records. These records are aggregated into cohort levels that include dimensions of rank, MOS, years of service, time in grade, and year. Marine Corps regulations use these dimensions to establish constraints for promotions, lateral moves, retirements, and strength reductions.

Wide variation in MTYP decision variables are discouraged with explicit constraints. Forceouts and lateral moves are also discouraged by adding costs for these undesirable activities. MTYP output lists the number of desired accessions, promotions, lateral moves and forceouts for each year in the time horizon. These results provide promotions that tie the rank structure together, lateral moves that cover promotion and accession shortages in cohorts, and forceouts to help reduce excess personnel.

Average MTYP LP solve time is less than thirty minutes on a Pentium IV 2 Ghz personal computer, using the GAMS modeling system and the CPLEX LP solver. Kaplan-Meier survival estimators for MTYP can be computed for forty selected occupational fields in forty-nine minutes using S-Plus edition 6 software on the same computer.

I. INTRODUCTION

This thesis develops an optimization model of accessions, promotions, and other decisions that determine the enlisted rank strength of the Marine Corps. The model discourages wide variability in accessions and promotions, and minimizes deviations from targeted strength levels over a thirty-year horizon. Key inputs to the model are attrition rate estimates. These are computed through Kaplan-Meier statistical estimates of each Marine's "survival probability," i.e., the probability that a Marine's career lasts a specified number of years.

The optimal set of decision variables is calculated with a set of linear programs (LPs). Each LP optimizes the manpower structure within an occupational field by varying the number of recruits, promotions, and other moves that Marines make into and out of occupational specialties. Each LP is initialized with force strength data taken from the current Marine Corps database. This real-time force structure data gives a detailed approximation of the force structure before the model's recommended decisions are put into effect. Force strength targets are levels set by Headquarters Marine Corps, Manpower Division.

A. BACKGROUND

The Marine Corps recruits between 29,000 and 36,000 enlisted personnel per year into its active duty forces (Nguyen 1997). Congressional mandates instruct the Marine Corps to maintain its strength at no less than ½ % below and no more than 1% above 174,000 officers and enlisted personnel (Nguyen 1997). Enlistment quotas are issued to recruiters in order to fill voids in the manpower structure that arise from attrition and promotions. The requirements issued to the recruiters are provided by the Marine Corps manpower modeling process which this thesis addresses.

The current Marine Corps enlisted manpower modeling process relies on three separate models. The Enlisted Accessions Model (EAM) estimates the number of recruits needed at the entry level of each military occupational specialty (MOS). The model factors in how attrition reduces the number of Marines in their first four to five

years of service (Headquarters Marine Corps Study Directive 2 Feb 2001). The estimate is crudely based on the steady-state requirement for Marines specified by MOS, rank, and year. This requirement is really a target the process attempts to meet; it is referred to as the Force Structure Planning Group Grade-Adjusted Recapitulation (fspggar) (Marine Corps Order 5311.1C).

The second model is called the First Term Alignment Plan (FTAP). FTAP models the demand for Marines in a particular MOS as they enter their second contract, which usually comes between three and five years of service (Headquarters Marine Corps Study Directive, 2 Feb 2001). The fspggar target number for Marines required in an MOS is entered into the model and FTAP estimates the number of Marines needed to reenlist, after their first contract expires, to meet the steady-state demand for Marines between three and five years of service.

In recent years, a need was identified for a model covering the second and third reenlistment/ terms, from eight to twenty years of service. The STAP (Subsequent Term Alignment Plan) model was the result. STAP is based on the same methodology as EAM and FTAP and was implemented in November of 2001.

All models measure the number of Marines in each MOS, but without the detail needed to meet fspggar targets accurately. In particular, EAM, FTAP and STAP track MOS and years of service to determine cohort strengths, but fspggar targets Marines by MOS and rank. To reach any rank beyond E-3 (Lance Corporal), a Marine must be promoted competitively against others in his MOS. Promotions are governed by a set of rules that involve years of service, and time in grade. Therefore, to properly model the rank structure the model should track year, MOS, rank, number of years in a rank (time in grade or "tig"), and number of years in the service (years of service or "yos").

The three models are not linked and estimates coming from one model must be entered, manually, into another model (Headquarters Marine Corps Study Directive 2 Feb 2001, pp. 2). In particular, the predicted number of Marines at the end of their four-year contract in EAM is not linked with the number of Marines in that MOS in the fifth year of FTAP.

EAM models attrition as a discrete-time Markov process to determine the initial number of Marines needed to fill the steady-state requirements of each MOS. FTAP uses the same paradigm to determine the number of Marines the USMC needs to reenlist in order to man the structure in each MOS for Marines in their second term. STAP continues this methodology for Marines reenlisting beyond their second term. The attrition estimates for the current models do not incorporate rank-induced differences. This is probably a mistake since, for instance, a Marine who is an E-3 (Lance Corporal) might be more inclined to reenlist after promotion to E-4 (Corporal). There are also a number of MOSs that have been recently created and thus have no statistics to estimate attrition accurately.

None of the three models currently used for manpower planning explicitly incorporates promotions. The models should not be separate entities, but rather a single model that tracks force levels throughout the twenty-year time horizon covered by the three separate models. Attrition estimates need to incorporate the use of rank-induced differences as well, and new MOSs require attrition estimates, presumably based upon attrition from similar MOSs.

B. PROBLEM STATEMENT

An enlisted manpower planning model should help in determining levels of recruits needed, and the number of reenlistments, promotions, forceouts, and lateral moves. (A Marine who changes his original MOS to another has made a "lateral move.") These decisions are based on balancing current cohort levels with fspggar targets which need to be satisfied. (A cohort is a group with the same rank, time in service, time in grade, and MOS.)

The Marine Corps has a need for an enlisted planning model that can accomplish these things throughout a thirty-year time horizon. For the purposes of the proposed model, a recruit is a trained Marine who has been through basic and MOS-specific training. Cohorts of recruits will be modeled by "accession variables." Promotions consist of a Marine moving up to the next rank in his career path. A Marine is laterally

moved when he is retrained in an MOS outside of his original career-track. A Marine is forced out of the service if a lateral move or promotion is not feasible for that Marine due to heavy competition for promotion or reenlistment slots, or due to the Marine's own poor performance.

This thesis develops a manpower optimization model called the Marine Thirty-Year Plan (MTYP) that will estimate necessary accessions, promotions, lateral moves, and forceouts over a thirty-year time horizon. MTYP uses a set of LPs to measure and minimize deviation from the fspggar targets in each MOS, at each rank over the time horizon. The set of linear programs encompasses forty different occupational fields in the Marine Corps. An occupational field is a group with similar MOSs. For instance, the 01 occupational field consists of the MOSs numbered 0121, 0151, 0161, and 0193, all of which are administrative in nature. (Occupational fields are designated by the first two digits that their MOSs share.)

Critical inputs for MTYP are estimates of attrition between years, so great care is needed making these estimates. Attrition is estimated, not just for initial years, but for all years of service. New MOSs are analyzed for similarity to current, or discontinued MOSs, so that attrition estimates can be calculated and used. All estimates are analyzed to see if differences between ranks are significant. All data sets used to calculate estimates are analyzed to see if they contain enough samples to yield accurate estimates. (Data taken from a new MOS that has a history of 100 active duty Marines, with only two Marines discharged, cannot provide an accurate attrition estimate.) This data is also analyzed for anomalies that may affect estimates.

The term "Thirty-Year Plan" does not mean that MTYP will be able to accurately predict the force structure thirty years into the future. It is meant to convey the maximum length and variation of an enlisted Marine's career, which can span thirty years, nine ranks, and several MOSs. MTYP does explicitly model thirty years of manpower decisions, but it is meant to be used to make decisions in the context of a "rolling horizon." Additional simulation studies will need to be carried out to determine how well MTYP performs in this environment.

The lack of temporal integration in current Marine Corps manpower models can cause deviation from fspggar targets. This can, in turn, lead to a top-heavy structure with too much supervision and little chance of promotion in some MOSs, and/or personnel shortages in other MOSs. Deviations from fspggar targets also lead to heavy use of lateral moves to balance MOSs. Lateral moves into and out of an MOS cost training dollars, so this methodology is minimized as much as possible. Forcing out good Marines due to surpluses in an MOS is bad for morale, is a disservice to those Marines forced out, and is wasteful of training and manpower resources. MTYP will provide integration among the different ranks, the thirty-year time horizon, and the possible MOS changes that a Marine might encounter during his career. The result should be a manpower planning tool that increases readiness, lowers training costs, and benefits morale.

C. THESIS OUTLINE

Chapter II details the enlisted manpower planning process in the Marine Corps. Chapter III describes optimization manpower models, with specific assumptions and formulations for the MTYP linear program. Chapter IV describes the statistical techniques, assumptions, and formulations used to estimate attrition rates used by MTYP. Chapter V gives computational results. Chapter VI gives conclusions and recommendations for future work.

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II. ENLISTED MANPOWER PLANNING IN THE MARINE CORPS

The Marine Corps primarily adjusts its manpower structure by varying the number of accessions, promotions, lateral moves, and forceouts. The office that makes these decisions is Headquarters Marine Corps, Manpower and Reserve Affairs (M&RA); it is responsible for "…preparing plans, policies, programs, and instructions on manpower matters to implement the Commandant's policies and decisions." (Headquarters Marine Corps website: https://osprey. manpower. usmc.mil/manpower/ mi/mra_ofct.nsf/m&ra+home, February 2002)

The planners in the enlisted plans section of M&RA prepare staffing plans that ensure that the number of Marines qualified in each primary MOS at each rank is as close as possible to the established number set forth by the fspggar. To do this, they set policies that are reflected in recruiting goals, MOS training goals, promotions, separations, lateral moves, and other policies that shape the force of the enlisted structure. This chapter describes the Marine Corps regulations and procedures in training, promoting, laterally moving, and retiring enlisted Marines. These regulations and procedures guide M&RA in defining the enlisted Marine manpower system and should be modeled explicitly in any new model such as MTYP.

A. RECRUITING AND TRAINING

Marines normally enter the service at the basic-training level with no occupational specialty and at the rank of E-1 (Private). At the conclusion of basic training, Marines are sent to Marine Combat Training, and then to their primary MOS school. When they depart basic training they are assigned a training MOS until they complete their primary MOS school and/or any follow-up training. Upon completion of primary MOS training, a Marine is assigned a primary MOS that describes his specialty and confirms that he is qualified to perform that job. The fspggar primarily targets E-3s in training MOSs and primary MOSs (E-1s and E-2s are not targeted in primary MOSs). To simplify the

modeling process, only primary MOSs will be considered. An Excel depiction of the fspggar for the 01 occupational field is shown in Figure 1.

MOS	E9	E8	E7	E6	E5	E4	E3	E2E1	Total
0100	0	0	0	0	0	0	444	0	444
0121	0	0	0	0	487	673	1560	0	2720
0151	0	0	0	0	724	828	1480	0	3032
0161	3	7	29	50	71	85	185	0	430
0193	49	167	562	946	0	0	0	0	1724

Figure 1. Manpower Targets for Occupational Field 01.

Force Structure Planning Group Grade-Adjusted Recapitalization (fspggar) manpower targets for the 01 occupational field. This occupational field contains five MOSs with targets in ranks E-3 through E-9. MOS 0100 is a basic administration Marine and only has E-3s targeted. The values indicated are for numbers of Marines targeted for a particular rank and MOS.

B. PROMOTION

Promotions above the rank of E-3 (Lance Corporal) are usually awarded to a Marine after he has served a certain period of time in his present rank, has shown leadership ability commensurate with rank advancement, and a vacancy at the next rank exists. The values of yos and tig define the minimum parameters for a Marine to be considered for promotion. The value yos indicates how many years a Marine has been in service, starting from the date he signed his contract. The value of tig indicates how many years a Marine has held his present rank, and is reset to zero each time he is promoted. Minimum promotion requirements for each rank are set forth in the Marine Corps Promotion Manual, Volume 2 Enlisted Promotions (HQMC, *MCO P1400.32C*, October 2000). The values of yos and tig are used to group Marines at a grade and rank into seniority groups for promotion, the goal being to promote the most senior Marines first. The indices tig, yos, rank, MOS, and year form a five-dimensional variable that define promotion requirements.

Promotion up to and including E-3 is automatic, based upon time in service and time in grade, and not subject to competitive promotion selection among peers. Promotion to E-4 (Corporal) and above is subject to competitive promotion procedures. Since fspggar targets primarily covers the ranks of E-3 and above, this thesis will be

concerned with those ranks. Typically a Marine is an E-3, (or shortly will be) by the time he reports to his first unit at the completion of his primary MOS training.

Table 1 displays the minimum time in grade and years of service, needed for promotion to the next rank.

Promotion to	**Time in Grade**	**Years of Service**
E-4/Corporal	8 months	1 year
E-5/Sergeant	1 year	2 years
E-6/Staff Sergeant	27 months	4 years
E-7/Gunnery Sergeant	3 years	6 years
E-8/Master Sergeant or1st Sergeant	3.5 years	8 years
E-9/ Master Gunnery Sergeant or Sergeant Major	3 years	10 years

Table 1. Minimum Time in Grade and Years of Service Requirements for Promotion.

Promotions to the next rank require that a Marine serve a minimum amount of time in rank and service. For instance, an E-3 (Lance Corporal) must serve 8 months as an E-3, and have 1 year of service before he is eligible for promotion to E-4.

When a Marine's initial contract time is complete, that Marine reenlists or leaves the service. If a Marine's MOS strength exceeds the fspggar target, he may not be given the opportunity to reenlist in his original MOS. He may have to move to an "open" MOS, i.e., one that is under-strength. He may also be given the choice to move to another MOS as an incentive to reenlist. Or, he may not be allowed to reenlist, and he is forced out.

As stated above, several related MOSs may be grouped together into what is known as an occupational field, or occfield. Within an occfield, or in a few cases between two occfields, the system may promote a Marine out of one MOS and into another. These promotions are said to be between "feeder" and "career progression" MOSs. The combination of feeder and career progression MOSs is known as a "career

track" (HQMC, *MCO 1220.5J,* May 1999). In the 01 occfield (personnel administration), a possible career track is a promotion from E-5 (Sergeant) 0121 (Personnel Clerk) to E-6 (Staff Sergeant) 0193 (Personnel Administrative Chief). Once promoted to E-6, the Marine usually retains MOS 0193 for the remainder of his career (HQMC, *MCO P1200.7V,* October 2000).

In most cases several feeder MOSs feed into a single career progression MOS. The transition is made into the career progression MOS at a higher rank. This higher rank is usually the lowest rung of the career progression MOS rank ladder. However, there are also cases where a feeder MOS feeds into an MOS that also has Marines at lower ranks that have carried that designation since they entered the manpower system. For example, MOS 1361 (Engineer Assistant) feeds into MOS 1371 (Combat Engineer) at the rank of Master Sergeant. But MOS 1371 already contains Marines from the rank of Private up to Gunnery Sergeant.

The career-track-specific variations between occupational fields makes it necessary for the manpower planner to construct constraints with the same basic structure, but which account for the variations associated with different occfields with respect to career-track progress.

A Marine occupies a fspggar target position once he reaches the rank of E-3. Any rank higher than E-3 can only be filled by promoting or laterally moving a Marine into that position. The promotion or separation of a Marine at a rank above E-3 sets a chain of events into motion, involving all the Marines beneath his rank in a career track. An E-9 (Master Gunnery Sergeant) retirement can involve the promotion of an E-8 to E-9 to fill his spot, an E-7 to replace the E-8, and so on down the rank structure. Each vacancy and promotion causes a ripple effect all the way back to an accession at the rank of E-3.

Discharges and retirements do not always occur at regular intervals and in the same numbers. A group of individuals can depart the service nearly simultaneously and cause a rash of promotions and accession requirements. There could also be a period of several years when no Marine in a cohort departs, and promotions stagnate in the corresponding occupational field. A wide swing from 20% of a rank in an MOS promoted in one year, to 0% for the next year has an adverse effect on morale and should

be avoided if possible. Figure 2 below shows the large variation in the number of promotions to Staff Sergeant for the 0161 MOS in the years 1992-2000. A comparison of Figures 2 and 3 below shows how the variation in the promotions to Staff Sergeant can carry down to the promotions to Sergeant in the same MOS.

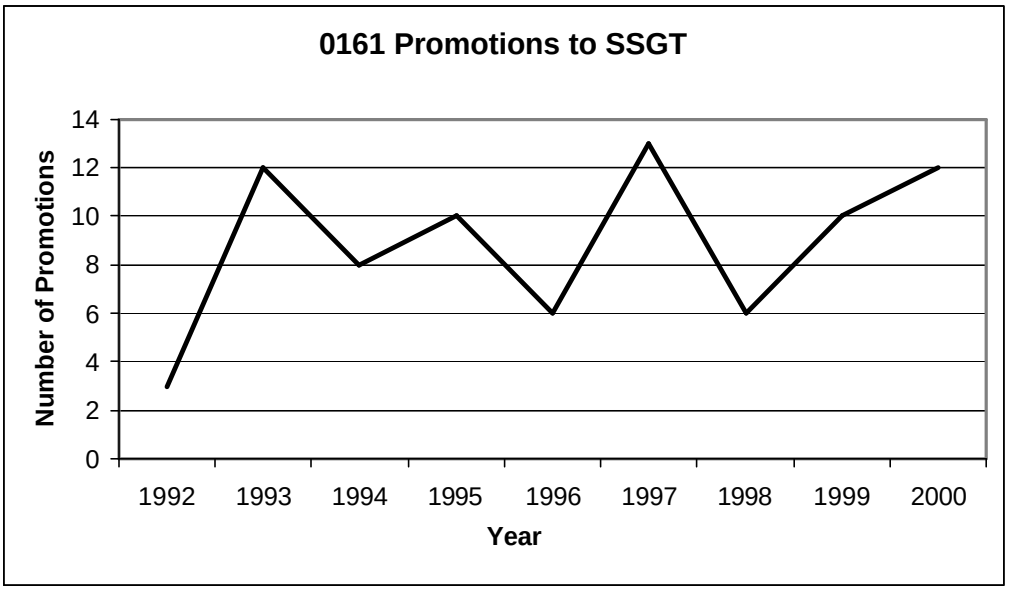

Figure 2. SSgt Promotions 1992-2000 for MOS 0161

There is significant variation in the number of promotions to Staff Sergeant (E-6) in the 0161 MOS (Postal Clerk). The number of promotions during 1992-2000 varied from 3 to 13.

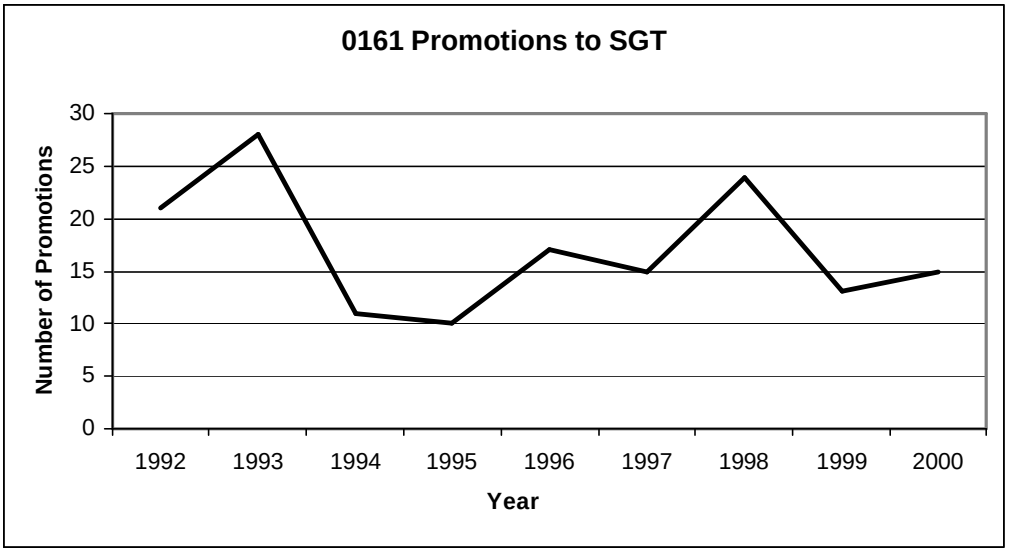

Figure 3. Sgt Promotions 1992-2000 for MOS 0161

There is significant variation in the number of promotions to Sergeant (E-5) in the 0161 MOS. The number of promotions during 1992-2000 varied from 10 to 28. The widest swing was in 1993-1994, when promotions oscillated from 28 to 11.

C. LATERAL MOVES

Any model of the enlisted manpower system must incorporate lateral moves between career tracks. Lateral moves give manpower planners flexibility in filling shortfalls and reducing overages in many MOSs. Lateral moves are typically only allowed into an MOS that is under its fspggar target, from an MOS that is over its target.

Marines must meet the minimum requirements of an MOS before they are allowed to make lateral moves. Marine Corps Order 1220.5 gives guidance that lateral moves will normally not be approved beyond a Marine's first reenlistment contract, typically between three and six years of service.

Lateral moves between MOSs are usually fairly costly in terms of re-training and relocating Marines, and may induce morale problems for the Marine making the transition, or the morale of Marines in the career field into which the Marine is transitioning to (CNA *CRM 94-105,* September 1994). However, some MOSs require Marines to make a lateral move into them. A counter-intelligence specialist (MOS 0211) is one such MOS. The reason behind making Marines laterally move into MOS 0211 is to draw from a pool of Marines that have proven themselves in the Fleet Marine Force as

being trustworthy enough to handle the rigors of counter-intelligence (HQMC, *MCO P1200.7V*). Other lateral moves can be indicators of inherent weakness in the manpower planning system for forecasting necessary manning levels. Any manpower planning model should strive to minimize the number of lateral moves. If there is no way to avoid lateral moves, then an effort should be made to forecast necessary moves in order to give planners and recruiters the maximum amount of time possible to fill slots with reenlisting Marines.

D. SEPARATIONS

Marines in all MOSs depart from the service when their contract expires, when they have medical problems, for hardship reasons, and for legal reasons. Attrition calculations would be simple if Marines only departed the service at the expiration of a contract, or at retirement. This is not always the case, but maximum term limits must be incorporated in any reasonable manpower model. These limits keep the model from generating unrealistic cohorts that are not encountered in the enlisted force. For instance, a cohort of E-4s would not be allowed to continue service past eight years in such a model.

RANK	Max Length of Service/Mandatory Retirement in Years
E-4/Corporal	8
E-5/Sergeant	13
E-6/Staff Sergeant	20
E-7/Gunnery Sergeant	22
E-8/1st Sergeant or Master Sergeant	27
E-9/Sergeant Major or Master Gunnery Sergeant	30

Table 2. Maximum Length of Service for Ranks E-4 and Above.

A Marine that reaches these service limits before promotion to the next rank must leave the Marine Corps. These limits were placed to control the enlisted ranks and, "…curb our escalating career force growth…" in 1985 (MARADMIN Number: 049/98, 1998). "Curbing escalating career force growth" refers to keeping the Marine Corps from becoming top-heavy with a surplus of E-4s and above.

Table 2 shows the maximum length of service for E-4s and above. If a Marine reaches E-6 or above, he or she is allowed to retire after twenty years of service. A Marine who accepts promotion at the E-6 level or above incurs a two year obligation of service (HQMC, *MCO P1400.32B*).

Marines who are not promoted before they reach length-of-service limits for a given rank are separated or "forced out" of the service. Forcing Marines out is detrimental to morale in an MOS, but is a part of the system and must be modeled. This policy is commonly referred to as an "…up or out policy" (MCBUL 5314, *ECFC Program*). A good manpower model would seek to minimize the number of Marines who are forced out due to lack of promotion or reenlistment prospects.

III. OPTIMIZATION MANPOWER MODELS AND MTYP

The Marine Corps enlisted force structure can be modeled using a set of LPs with decision variables that represent the primary inputs for the model, and also represent the primary methods by which enlisted planners can manipulate the system. No model can forecast the necessary decision variable levels with perfection, but well-designed LPs built with accurate estimates can be beneficial to the manpower planner

A. PROBLEM ASSUMPTIONS

This section deals with assumptions that are made to simplify model formulation.

Marines are assumed to be E-3s when they enter the system. Ranks E-1 and E-2 are not used in the model because time spent occupying those ranks is brief (six months each), and the omission reduces the number of possible cohorts to model. E-3s who are not promoted to E-4 by four years of service will be dropped from the model (i.e., forced out). Service limits from Table 2 (page 13) also cause a cohort to be forced out, when the max yos limit is reached.

Training MOSs that have fspggar targets are not modeled in MTYP. Marines entering the system are assumed trained and established in their primary MOSs. MOSs that extend a Marine's training period longer than one year (basic through primary MOS school) might seem problematic. But this situation can be modeled so that no attrition occurs in such MOSs before year one. For instance, a Marine who is an Aerial Navigator-Trainee (MOS 7371) can be in training for two years from the time he starts basic training. If he does not make it through training, he will usually be retrained in another MOS. The confirmed MOS cohort of Aerial Navigator (MOS 7372) is not affected by his attrition.

A discount rate of 1% per year is used to reduce the effect of missed targets far out in the time horizon. The discount factor for year t of the horizon is thus $w_t = .99^t$.

Another assumption is that MTYP can be modeled as a (generalized) network flow model with side constraints. Grinold (1983) advocates the use of network flows to model manpower systems to model "…the interaction between different classes through

time." The construction of a network to model the Marine Corps enlisted structure is accomplished using the cohorts as "manpower stocks," with arcs between the stocks carrying Marines through the transitions to the next cohort. Promotions, lateral moves, transitions out of the Marine Corps, and transitions between cohorts are all modeled as flows. Attrition as cohorts flow through time is modeled by loss factors on arcs, so the underlying model is actually a generalized network (Grinold 1983). The model has side constraints to limit year-to-year variations in certain decision variables, to enforce "fairness" considerations, etc.

B. PROBLEM FORMULATION

The MTYP LP is described in this section. A separate LP is solved for each occupational field, forty in all. MTYP optimizes cohort strengths by adjusting promotions, lateral moves, forceouts, and accessions subject to constraints on year-to-year variations of certain values and subject to some "fairness constraints." MTYP outputs the optimal cohort inventories and number of promotions, lateral moves, accessions and forceouts for each year in the time horizon. All variables are in units of Marines.

1. Definition of Terms

rank	Relative status of a Marine in the Marine Corps. Enlisted ranks start at E-1 and end at E-9. MTYP uses the fspggar targeted ranks of E-3 to E-9.
MOS	Military occupational specialty. A number that designates a Marine's occupation within the manpower system (i.e., MOS 0121 is an Administrative Personnel Clerk).
feeder MOS	An MOS that feeds, or can be promoted into a "career progression MOS."

career progression MOS	A special MOS that has several feeder MOSs that supply it through promotions.
time in grade	The number of years a Marine has at his present rank. Time in grade is reset to zero when a Marine is promoted or demoted.
years of service	The number of years a Marine has served in the Marine Corps. Years of service starts from the time a Marine enters the Marine Corps.
cohort	A cohort is a group with the same rank, time in service, time in grade, and MOS

2. Indices

$r \in R$	rank of Marine
$r' \in R$	rank promoted to
$m \in M$	MOS of Marine
$m' \in M$	"feeder" MOS m' feeds into MOS m''
$m'' \in M$	MOSs fed from "feeder" MOSs on promotion
t	year of planning horizon
$g \in G$	time in grade (tig)
$y \in Y$	years of service (yos)

3. Sets

$(r, y) \in RY$	Allowed combinations of rank r and yos y. Combinations are based on minimum time in service for promotion restrictions from Table 1, and

	maximum length-of-service restrictions from Table 2. For instance, an r = E-4 cannot exceed more than $y = 8$.
$(r, g) \in RG$	Rank r and tig g are compatible for present rank. Compatibility requirements are based on minimum time-in-service restrictions from Table 2.
$r'(r)$	A Marine is always promoted from rank r to rank $r'(r) = r + 1$.
$(r, m) \in RM$	Rank r and MOS m are compatible according to standards set forth in MCO p1200.7, the Marine Corps MOS manual. For instance, MOS 0121 includes the ranks of E-3 to E-5.
$m' \in M^{-}(m'')$	The set of feeder MOSs m' that can feed career progression MOS m'' according to MCO p1200.7. For instance, feeder MOSs 0121 and 0151 feed into career progression MOS 0193.
$m'' \in M^{+}(m')$	The career progression MOSs m'' that can be fed by "feeder" MOS m' according to MCO p1200.7. For instance, feeder MOSs 0121 and 0151 can feed career progression MOS 0193. ($\|M^{+}(m')\| = 1$ for all instances the author is aware of.)
$(r, g) \in RG^{min}$	tig g meets minimum requirement for promotion from rank r to rank $r'(r)$. Minimum requirements are based on minimum tig promotion restrictions from Table 1. For example, rank r = E-4 must have $g \geq 1$ to be eligible for promotion to r = E-5.
$(r, m, y, g) \in RMYG$	Combined compatibility requirements for a rank r. Rank r and year of service y must be compatible in

	RY, rank r and MOS m must be compatible in *RM*, and rank r and time in grade g must be compatible in *RG*.
$(r, m, y, g) \in pRMYG$	Combined compatibility requirements for promotion from rank r to rank $r'(r)$ within an MOS. Rank r must be compatible with MOS m, yos y, and tig g in *RMYG*. Ranks r and $r' = r'(r)$ must be compatible for promotion in *RY*. Rank r must be compatible with tig g in RG^{min} for promotion to $r' = r'(r)$.
$(r, m', y, g) \in fRMYG$	Combined compatibility requirements for promotion from rank r to rank $r' = r'(r)$, from feeder MOS m' to corresponding career progression MOSs. Rank r, MOS m', tig g, and yos y must be compatible in *RMYG*. Rank $r' = r'(r)$, MOS m', tig g, and yos y must also be compatible in *RMYG*.
$(r, m, y, g) \in lRMYG$	Compatibility requirements to be laterally moved out of MOS m. Rank r must be compatible with MOS m, yos y, and tig g in *RMYG*. Year of service y must be more than minimum lateral move time *LATMIN* ($y = 3$) and less than maximum lateral move time *LATMAX* ($y = 10$).
$(r, m, y, g) \in aRMYG$	Feasibility (accession) requirements for Marines entering the system after primary MOS training. Rank r must equal the initial rank after training (E-3), yos y must equal the initial yos after training ($y = 1$), and tig must equal the initial tig after training ($g = 0$).

4. Data [units]

$c_{r,m,y}$	Estimated continuation rate coefficient for rank r, MOS m and yos y [fraction]; 1– continuation rate = attrition fraction.
$fg_{r,m,t}$	Force Structure Planning Group (fspggar) target numbers for rank r, MOS m, and year t [Marines]
w_t	Discount factor for fspggar targets in year t [unitless]; $w_t = .99^t$ in practice
l^{c-}	Cost for a lateral MOS move out of a cohort [$/Marine]
l^{c+}	Cost for a lateral MOS move into a cohort [$/Marine]
f^c	Cost for forcing Marines out of service [$/Marine]
p^a	Promotion-constraint additive constant [Marines]
$\hat{E}_{r,m,y,g,t}$	Size of cohort (r, m, y, g) at beginning of time horizon $t = 1$ [Marines]
$\hat{A}_{r,m,y,g,t}$	Size of accession cohort (r, m, y, g) at beginning of time horizon $t = 2$ [Marines]
p^f	Penalty for violation of fairness constraint (3.8)
LATMIN	Minimum year of service y where lateral moves are allowed ($y = 3$) [years]
LATMAX	Maximum year of service y where lateral moves are allowed ($y = 10$) [years]

5. Variables

For the purposes of this model, the four-tuple (r, m, y, g) corresponds to a cohort.

$E_{r, m, y, g, t}$	Number of Marines in cohort (r, m, y, g) at the beginning of year t
$P_{r, m, y, g, t}$	Number of promotions into cohort (r, m, y, g) at the beginning of year t
$P'_{r, m', m'', y, g, t}$	Number of promotions from feeder MOSs m', cohort (r, m', y, g), in year t, into $(r'(r), m'', y, g)$ at the beginning of year t, where m'' is a career progression MOS for m'.
$L^{+}_{r, m, y, g, t}$	Number of lateral moves into cohort (r, m, y, g) at the beginning of year t
$L^{-}_{r, m, y, g, t}$	Number of lateral moves out of cohort (r, m, y, g) at the beginning of year t
$F_{r, m, y, g, t}$	Number of Marines forced out of cohort (r, m, y, g) at the beginning of year t
$A_{r, m, y, g, t}$	Number of accessions into cohort (r, m, y, g) at the beginning of year t
$D^{-}_{r, m, t}$	Deviation below fspggar target in year t for rank r and MOS m
$D^{+}_{r, m, t}$	Deviation above fspggar target in year t for rank r and MOS m
$B^{-}_{r, m, t}$	Elastic variable for violating fairness constraint (3.8) and under-promoting from MOS m
$B^{+}_{r, m, t}$	Elastic variable for violating fairness constraint (3.8) and over-promoting from MOS m

6. Objective Function

Note that summations should only be taken over valid index sets. These sets are omitted for the sake of clarity.

$$\text{MINIMIZE} \sum_t \sum_r \sum_m w_t (D^+_{r,m,t} + D^-_{r,m,t} + B^+_{r,m,t} + B^-_{r,m,t}) + \sum_t \sum_r \sum_m \sum_y \sum_g w_t (l^{c+} L^+_{r,m,y,g,t}) + \sum_t \sum_r \sum_m \sum_y \sum_g w_t (l^{c-} L^-_{r,m,y,g,t}) + \sum_t \sum_r \sum_m \sum_y \sum_g w_t (f^c F_{r,m,y,g,t}) \tag{3.1}$$

The primary objective, represented by the terms:

$$\sum_t \sum_r \sum_m w_t (D^+_{r,m,t} + D^-_{r,m,t} + B^+_{r,m,t} + B^-_{r,m,t}),$$

is to minimize deviations from the force-structure planning group grade-adjusted recapitalization (fspggar) targets and reduce deviations from fed promotion fairness constraint (3.8). Together with the non-negativity of D^+ and D^- and the discount factor w_t these variables enforce:

$$D^+_{r,m,t} \geq \max\{0, \sum_y \sum_g E_{r,m,y,g,t} - fg_{r,m,t}\},$$

$$D^-_{r,m,t} \geq \max\{0, fg_{r,m,t} - \sum_y \sum_g E_{r,m,y,g,t}\},$$

respectively. The objective also assesses penalties to discourage lateral moves:

$$\sum_t \sum_r \sum_m \sum_y \sum_g w_t (l^{c+} L^+_{r,m,y,g,t}) + \sum_t \sum_r \sum_m \sum_y \sum_g w_t (l^{c-} L^-_{r,m,y,g,t}),$$

and assesses penalties to discourage Marines being forced out:

$$\sum_t \sum_r \sum_m \sum_y \sum_g w_t (f^c F_{r,m,y,g,t}).$$

7. Constraints

The main inventory constraint computes the inventory of Marines in each cohort at the end of each year. All of the summations are only over valid index sets. The constraints balance lateral moves in, promotions in, and attrited carryover from the previous year against Marines forced out, promotions out, and lateral moves out. Fed promotions are only summed over promotions into a cohort; there are no feeder MOSs that feed into more than one career progression MOS.

Note: The following defines a completely general case of the inventory constraint in which a cohort can access, move laterally out or in, be promoted out or in, etc. In reality only some of these variables will be defined for any such constraint. Whether or not a variable should appear is determined through the sets *RMYG*, *lRMYG*, etc.

$$\begin{aligned} E_{r,m,y,g,t} = {} & c_{r,m,y-1} E_{r,m,y-1,g,t-1} + L^{+}_{r,m,y,g,t} - L^{-}_{r,m,y,g,t} \\ & - F_{r,m,y,g,t} + A_{r,m,y,g,t} + \sum_{g'} P_{r-1,m,y,g',t} - P_{r,m,y,g,t} \\ & + \sum_{m' \in M^{-}(m')} P'_{r,m',m,y,g,t} - \sum_{m'' \in M^{+}(m)} P'_{r,m,m'',y,g,t} \end{aligned}$$

$$\begin{aligned} & \forall\ r, m, y, g, t > 1, \\ & E_{r,m,y,g,1} \equiv \hat{E}_{r,m,y,g,1} \ \forall\ r, m, y, g \\ & A_{r,m,y,g,2} \equiv \hat{A}_{r,m,y,g,2} \ \forall\ r, m, y, g \end{aligned} \tag{3.2}$$

Promotion constraints for each cohort restrict the number of promotions out to within ten percent of previous year's number of promotions. The positive constant p^a is

added in (3.4) to keep promotions from going to 0 in some year, and remaining at 0 for the rest of the time horizon:

$$\sum_{y} P_{r,\, m,\, y,\, g\,=\,0,\, t} \;\geq\; .9 \sum_{y} P_{r,\, m,\, y,\, g\,=\,0,\, t\,-\,1} \quad \forall\ (r,\ r',\ y,\ g) \;\in\; pRMYG \tag{3.3}$$

$$\sum_{y} P_{r,\, m,\, y,\, g\,=\,0,\, t} \;\leq\; 1.1 \sum_{y} P_{r,\, m,\, y,\, g\,=\,0,\, t\,-\,1} \;+ p^{a} \quad \forall\ (r,\ r',\ y,\ g) \;\in\; pRMYG \tag{3.4}$$

Promotion constraints for each cohort restrict the number of fed promotions out to within ten percent of previous year's number of fed promotions. The positive constant p^a is added in (3.6) to keep promotions from going to 0, and remaining 0 for the rest of the time horizon:

$$\sum_{y} \sum_{m'' \in M^{+}(m')} P'_{r,\, m',\, m'',\, y,\, g\,=\,0,\, t} \;\geq\; .9 \sum_{y} \sum_{m'' \in M^{+}(m')} P'_{r,\, m',\, m'',\, y,\, g\,=\,0,\, t-1}$$
$$\forall\ (r,\ m',\ \ y,\ g) \;\in\; fPRMYG \tag{3.5}$$

$$\sum_{y} \sum_{m'' \in M^{+}(m')} P'_{r,\, m',\, m'',\, y,\, g\,=\,0,\, t} \;\leq\; 1.1 \sum_{y} \sum_{m'' \in M^{+}(m')} P'_{r,\, m',\, m'',\, y,\, g\,=\,0,\, t-1} \;+ p^{a}$$
$$\forall\ (r,\ m',\ \ y,\ g) \;\in\; fPRMYG \tag{3.6}$$

Forceout constraint restricts the total number of forced separations to ten percent or less of the total number in that cohort:

$$\sum_{y} \sum_{g} F_{r,m,y,g,t} \leq .1\, E_{r,m,y,g,t}$$
$$\forall\ (r, m, y, g) \in RMYG$$

(3.7)

Promotion constraint that restricts the number of promotions from a feeder MOS, into a career progression MOS to a number that is proportional to the number of Marines in that feeder MOS to the total number of Marines in all MOSs that feed into the career progression MOS:

$$\sum_{y} P'_{r,\underline{m}',m'',y,g=0,t} = \frac{\sum_{y} \sum_{g} fg_{r,\underline{m}',y,g,t}}{\sum_{m' \in M^{-}(m'')} \sum_{y} \sum_{g} fg_{r,m',y,g,t}} \sum_{y} \sum_{m' \in M^{-}(m'')} P'_{r,m',m'',y,g=0,t} + B^{+}_{r,m,t} - B^{-}_{r,m,t}$$

$$\forall\ (r, m'',\ y,\ g) \in fRMYG,\ \ \underline{m}' \in M^{-}(m'')$$

(3.8)

Accession constraints restrict the number of accessions to within ten percent of the previous year's accessions for each accessible cohort. Initial levels of Marines input into the system from their primary MOS training should be relatively close to the number of Marines input from the year before. The upper limit is modified by a positive constant in case accessions go to zero in some year:

$$A_{r,m,y,g,t} \geq .9\, A_{r,m,y,g,t-1} \qquad \forall\ (r, m, y, g) \in aRMYG$$

(3.9)

$$A_{r,m,y,g,t} \leq 1.1\, A_{r,m,y,g,t-1} + p^{a} \qquad \forall\ (r, m, y, g) \in aRMYG$$

(3.10)

Nonnegativity restrictions are:

$$E_{r,m,y,g,t}, P_{r,m,y,g,t}, P'_{r,m,m',y,g,t}, L^{+}_{r,m,y,g,t}, L^{-}_{r,m,y,g,t} F_{r,m,y,g,t'}$$
$$F_{r,m,y,g,t}, A_{r,m,y,g,t}, D^{+}_{r,m,t}, D^{-}_{r,m,t} \geq 0$$

for all defined indices.

(3.11)

C. DISCUSSION

In MTYP's inventory balance constraints, all actions are assumed to occur on January 1 in year t except attritions that occur at 2359 on December 31 of year $t - 1$. Thus, cohorts on January 1 can be used to satisfy staffing targets for (the whole) year t. Promotions, lateral moves and forceouts all occur on January 1 from just-attrited forces.

In constraints (3.4), (3.6), and (3.10) the constant p^a is used as an additive constant to keep promotion and accession levels from being forced to zero. For instance, suppose A_t represents generic accessions in year t in some model and we add the constraints (analogous to these constraints without the p^a):

$$A_t = 1.1\ A_{t-1} \qquad \text{for all } t > 1.$$

Then if $A_{t-1} = 0$, this implies $A_t = 0$ for all following years in the time horizon

The accession variable $A_{r,m,y,g,t}$ for the second year of the model is fixed to $\hat{A}_{r,m,y,g,t}$ with data from the current accession rate used in the Marine Corps for that cohort. The initializing data $\hat{E}_{r,m,y,g,,t}$ for $t = 1$, is calculated from the current enlisted database value for that cohort.

IV. ESTIMATING ATTRITION COEFICIENTS

This chapter describes the statistical techniques used to estimate MTYP's attrition coefficients, and describes the results for select MOSs. MTYP's most critical data requirements are attrition coefficients or, equivalently, continuation rates (continuation rate = 1 – attrition coefficient).

A. ESTIMATING SURVIVAL PROBABILITIES

Attrition is sometimes called wastage. "The traditional way of approaching wastage is via rates." "…a 'crude' rate is obtained by dividing the number of leavers from a group in some interval of time by the number of those at risk of leaving." (Bartholomew et al. 1991, pg. 15) Bartholomew and co-authors go on, "…propensity to leave depends upon length-of-service, and in practice this seems to be the most important factor of all." The analysis of the attrition data supplied for this project uses this length-of-service paradigm in the construction of the continuation rates for cohort forecasting. Bartholomew et al. also discuss using a survivor function (defined below) as the statistical function that deals best with the case where "…we do not usually know the upper limit of service." The survivor function is the best method available to gauge probable length of service for a Marine, because when a Marine enlists at zero yos, we do not know if he'll survive (continue to serve) to yos one, or yos thirty.

The Kaplan-Meier estimator for survival probabilities (Kaplan and Meier 1958) is the basis chosen for estimating attrition coefficients. The Kaplan-Meier estimator is chosen because of its resilience to unobserved "deaths" that can occur outside the horizon of the study. For instance, if a Marine is discharged in his third year of service, and his discharge is not recorded properly, the Kaplan-Meier estimator representing his cohort will not be unduly biased by the omission (Kaplan and Meier 1958, pg. 3).

If $F_m(y)$ is the nonparametric continuous distribution of the time in service for a cohort of Marines with MOS m, then the survivor function $P_m(y)$ is defined by:

$$P_m(y) = 1 - F_m(y) \qquad \text{(Høyland and Rausand 1994),}$$

where $P_m(y)$ is the probability that a Marine will stay in the service beyond years of service y. The Kaplan-Meier estimator of $P_m(y)$, denoted by $\hat{P}_m(y)$, is based on the conditional probability of surviving to a year of service y given survival to $y - 1$. These conditional probabilities are calculated assuming independence between observations. For instance, suppose there is an initial cohort of 1000 trained Marines for each of two successive year groups in MOS m. (This example parallels an example in Kaplan and Meier.) Survivors from the groups number 800 and 850 after their first year of service. The estimate of survivor probability is:

$$\hat{P}_m(1) = \frac{800 + 850}{1000 + 1000} = .825 .$$

This is an estimated conditional probability and is referred to as the "reduced-sample estimate" by Kaplan and Meier. However, when moving on to the second year and considering the case where 700 survivors from the first group are in their second year of service and no data exists on the second group, probability of surviving from year zero to year two for the entire group is estimated as:

$$\hat{P}_m(2) = \frac{700}{800}\hat{P}(1) = (.875)(.825) = .722$$

(Kaplan and Meier 1958, pg. 3)

Let $\hat{E}_{r,m,y,g,t}$ be the number of Marines observed in cohort (r,m,y,g) at the beginning of year t, and let $\hat{D}_{r,m,y,g,t}$ be the number of discharges observed from that group in year t. Then the MOS-dependent Kaplan-Meier estimator for $\hat{P}_m(y)$ is:

$$\hat{P}_m(y) = \prod_{y'=1}^{y} \frac{\sum_r \sum_g \sum_t (\hat{E}_{r,m,y',g,t} - \hat{D}_{r,m,y',g,t})}{\sum_r \sum_g \sum_t \hat{E}_{r,m,y',g,t}}, \qquad (4.1)$$

Høyland and Rausand (pg. 401) conclude that the Kaplan-Meier estimator has the characteristics of an asymptotic normal distribution with confidence limits that can be determined using normal approximation.

There is evidence that basing survival probabilities on only MOS and yos is insufficient in providing MTYP with accurate coefficients for calculating cohort strengths in feeder MOSs; this evidence will be examined in Chapter V. In particular, rank may be an important factor in survival probability. The rank and MOS-dependent Kaplan-Meier estimator is:

$$\hat{P}_{r,m}(y) = \prod_{y'=1}^{y} \frac{\sum_{g}\sum_{t}(\hat{E}_{r,m,y',g,t} - \hat{D}_{r,m,y',g\ t})}{\sum_{g}\sum_{t}\hat{E}_{r,m,y',g,t}}.$$

$\hat{P}_{r,m}(y)$ will also be referred to as a "rank-stratified" estimator in Chapter V, in contrast to the "unstratified estimator" $\hat{P}_{m}(y)$.

In computing survival probability estimates, the following assumptions are made:

- All enlisted Marines will be discharged from service at or before thirty years of service is completed.
- All "surviving" Marines will be discharged at their term limits respective of their rank as shown in Table 2.
- All Marines are given a primary MOS upon completion of primary MOS school and discharged with a primary MOS.
- Data sets without sufficient sample size (less than thirty, say) can be combined or substituted with similar MOSs to provide the prerequisite sample size.

The Kaplan-Meier estimator provides a useful estimate for the probability that a Marine will survive to a given year of service from his initial year, but it needs to be modified to provide continuation rate coefficients that estimate the probability of surviving from one year to the next.

B. STATISTICAL FORMULATION

This section modifies the Kaplan-Meier estimator to provide continuation rate coefficients that estimate the probability of surviving from one year to the next.

Let $\hat{P}_m(1) = .950$, and $\hat{P}_m(2) = .900$. An initial cohort level of 1000 Marines would be expected to contain (1000)(.950) or 950 Marines in it after one year of service. The estimator $\hat{P}_m(2)$ provides the estimated force strength of 900 Marines after two years of service. To find the continuation rate coefficients for Marines between years one and two for an initial strength of 1000, the estimator for year two is divided by the year one estimator:

$$c_{m,\,y=2} = \frac{\hat{P}_m(2)}{\hat{P}_m(1)} = \frac{.900}{.950} = .947 \tag{4.1}$$

Multiplying the result by the cohort strength after one year, (.947)(950), a result of 900 Marines is obtained. This result is identical to the result found by multiplying the initial strength of 1000 by $\hat{P}_{r,m}(2)$. It can be shown that this result holds true for all initial strengths and estimators. A derivation to find $c_{m,y}$ given survival probabilities for years y and $y-1$ is:

$$\begin{aligned} &\Pr\{\text{Surviving to year } y \mid \text{survival to year } y-1\} \\ &= \frac{\Pr\{\text{Surviving to year } y \cap \text{surviving to year } y-1\}}{\Pr\{\text{Surviving to year } y-1\}} \\ &= \frac{P_m(y)}{P_m(y-1)} \\ &= c_{m,y}. \end{aligned} \tag{4.2}$$

The variance of the Kaplan-Meier estimator with ties computed by Kalbfleisch and Prentice (1980, pg. 14) and modified for the data and notation in this study is:

$$\text{var}(\hat{P}_m(y)) = (\hat{P}_m(y))^2 \sum_{y'=1}^{y} \sum_{r} \sum_{g} \sum_{t} \frac{\hat{D}_{r,m,y,g,t}}{\hat{E}_{r,m,y,g,t}(\hat{E}_{r,m,y,g,t} - \hat{D}_{r,m,y,g,t})} . \tag{4.3}$$

This formula is commonly referred to as Greenwood's formula. This variance can be used to compute confidence intervals on $\hat{P}_m(y)$. These confidence intervals are quite tight implying that confidence intervals for $c_{m,y}$ are also tight. However, because of a lack of time, actual confidence intervals on continuation rates are not computed.

C. MISSING OBSERVATIONS

The amount of data collected for MTYP is roughly three times the size of the enlisted force structure of the Marine Corps, but there are missing data points. Høyland and Rausand (pg. 399) argue that in the case of missing observations, it is best to use a survival probability of one in an interval with missing data. Bartholomew et al. (pg. 56) does not necessarily agree with this, and advocate the use of a "…simple curve capable of graduating such distributions…" Bartholomew et al. (pg. 56) also state, "An alternative is to fit a curve and use that as a basis for interpolation." While it may seem reasonable to use a probability of one for the missing observations, analysis of the manpower data presents some overall trends that make this unreasonable. This is shown to be the case in the results section of this chapter. For this reason, the method of least squares is used to smooth the distribution of survivor probabilities in the case of missing observations.

D. COMPUTATIONAL TOOLS

The statistical software package S-Plus is chosen for its availability and built-in functionality. S-Plus uses the Kaplan-Meier methodology as the default analysis type when invoking the built-in `survivor()` function. The S-Plus program `occfield()` written by the author (Appendix B) takes the discharge data and creates an

S-Plus `survival()` object. Missing estimates in the S-Plus object are filled in with least squares estimates using function `fill.in.MOS()` written by one of the thesis co-advisors (Buttrey) (Appendix B). The S-Plus `survival()` object returns a list of the times that a discharge is recorded, the number of discharges for that particular time, the standard error based on Greenwood's formula, the Kaplan-Meier estimates, and upper and lower 95% confidence boundaries. Since the data is uncensored, all records are run as deaths in the survival function. (A Marine service separation or discharge would be defined as a "death" in survivor terminology.) The resulting Kaplan-Meier estimates are extracted out of the `survival()` object by `occfield()`, converted into continuation rate coefficients and put into a 2 by 30 data matrix with years of service inserted into the second column. Missing years of service are located and the S-Plus least-squares estimation function `approx()` is used to interpolate the missing coefficients. A 1 by 30 vector of continuation coefficients is extracted from of the previous matrix and appended to a text file that can be read by the General Algebraic Modeling System (GAMS). `Occfield()` does this for 40 different MTYP LPs by creating 40 different data tables indexed by their respective occfields.

E. RESULTS

This section examines the survival probability and continuation rate estimates found with data from Marines who separated from the service.

The data set for this project was compiled and configured as requested from the Defense Management Data Center (DMDC) West. The dataset has over 445,000 records in it from Marines who separated between 1990 and 2000. From this dataset, it is possible to break down the number of Marines that separated from each MOS at a particular year of service.

Estimates for continuation rates are compiled by `occfield()`. Some of the smaller or newer MOSs with fewer than the preferred number of thirty records must be aggregated, but these are the exception. `Occfield()` automatically calculates continuation rates from MOSs whose numerical designation has changed by using data samples from the previous designation. For example, MOS 2513 (Construction

Wireman) was changed to MOS 0613, but the job has remained the same. `Occfield()` automatically uses data from MOS 2513 to calculate estimators for MOS 0613. For a list of MOS designation changes and substitutions, see Appendix D.

Figure 5 shows an S-Plus graph of the Kaplan-Meier estimates for MOS 7372 (KC-130 Navigator). This is a small MOS with an aggregate fspggar target number of 80 Marines over all ranks. The graph shows the estimated probability that a Marine in MOS 7372 will still be in service at a particular year *y*.

Figure 5 shows that the probability of remaining in service to year four drops significantly from years one through three. This occurs because the normal contract for an enlisted Marine expires between year four and year six and if that Marine does not reenlist he separates from the service. This probability drop is also significant at year twenty-one. The minimum amount of time required before retirement is twenty years as shown in Table 2. It is reasonable therefore that the probability that a Marine remains in from year zero to year twenty-one is significantly less than the probability a Marine remains in from year zero to year twenty. Dashed lines bounding the dotted line intercepting the survival probabilities denote the 95% upper and lower confidence boundaries for the data set.

The probabilities shown in Figure 5 are the basis for the construction of the continuation rates. MOS 7372 continuation rates are shown in Figure 6. This figure shows that the continuation rate drops significantly from yos three to yos four, but starts increasing from yos four to five. This is reasonable as it covers the period when a Marine would sign a second contract and continue service. Probabilities dip at other points, which might be points where contracts expire and Marines do not reenlist. There is a slight dip at seventeen years, which is the last year that the Marine Corps can separate a Marine without paying retirement benefits. Continuation rates are steady at eighteen and nineteen years of service, the years immediately preceding the minimum retirement year (20).

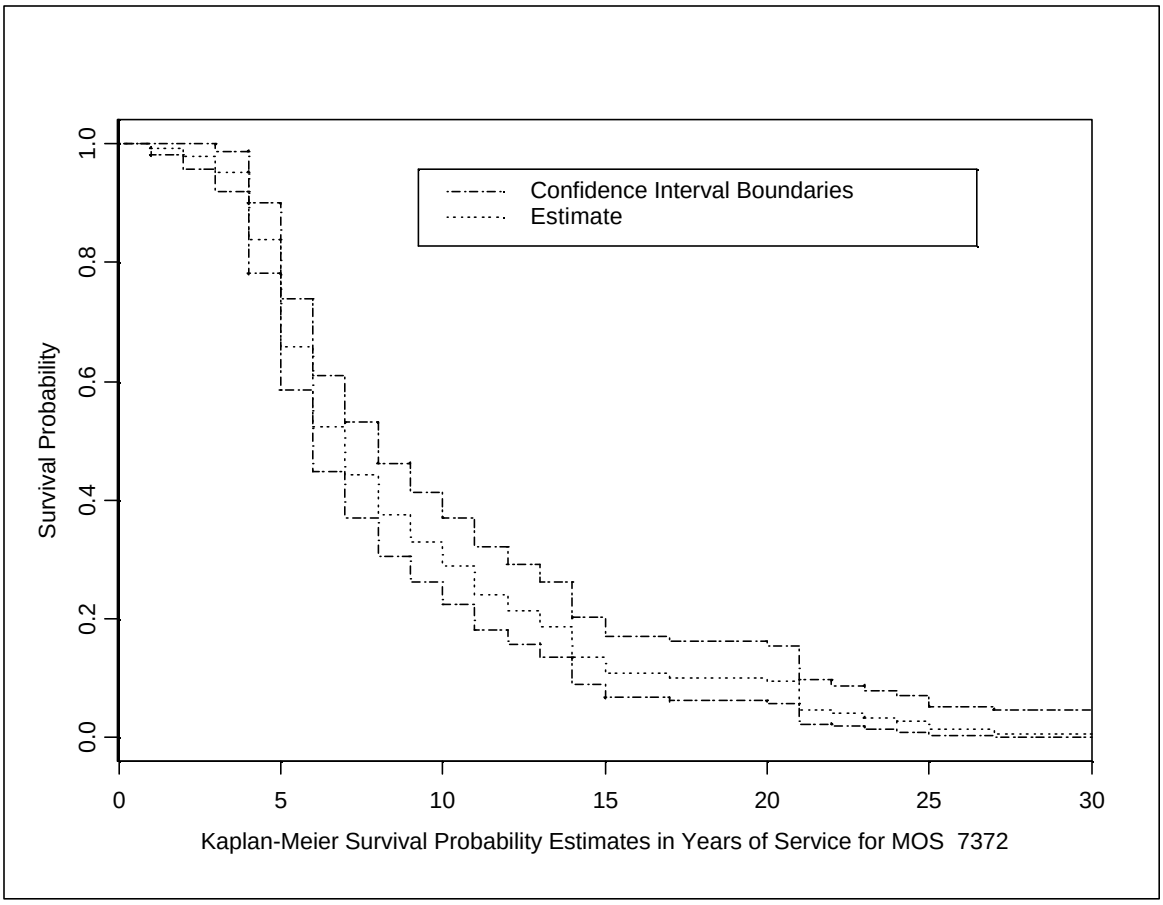

Figure 5. MOS 7372 Survival Probability Estimates

Kaplan-Meier MOS 7372 (Aerial Navigator) estimates show the probability that a Marine in the 7372 MOS will still be in the service at a particular year. Confidence interval boundaries are for a confidence level of 95%.

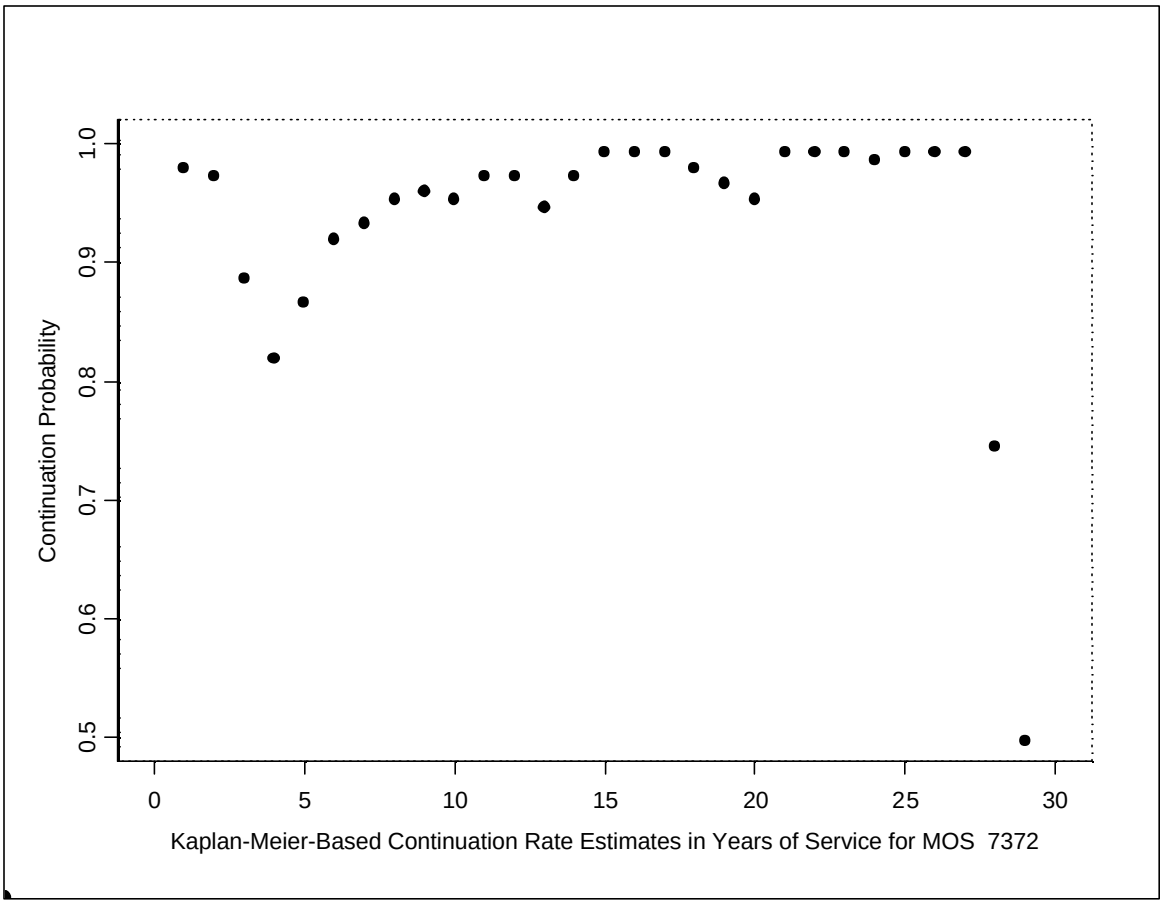

Figure 6. MOS 7372 Continuation Rate Estimates

MOS 7372 continuation rates constructed from MOS 7372 survival probabilities. The Kaplan-Meier survival probabilities show the probability that a Marine will be in service up to a given year, from yos zero. The continuation rates show the probability that a Marine will continue service one year to the next.

Figures 5 and 6 are particular for MOS 7372, but different MOSs with larger sample sizes show probability shapes similar to those figures. Figures 7 and 8 show the Kaplan-Meier survival probabilities and corresponding continuation rate estimates for MOS 0161 (Administrative Postal Clerk). The narrow confidence boundaries for this data set reflect MOS 0161's larger sample size in comparison to MOS 7372. All confidence intervals in this section are at the 95% level.

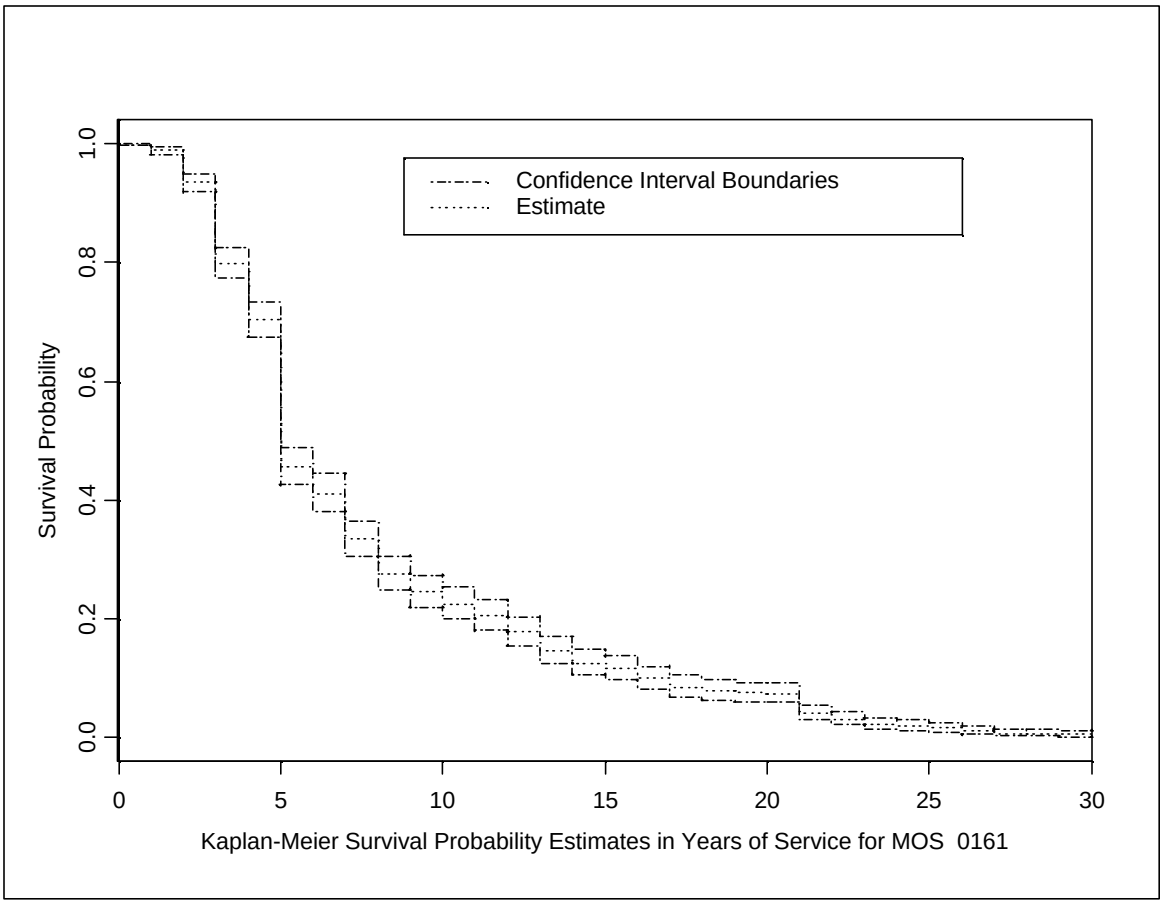

Figure 7. MOS 0161 Survival Probability Estimates

Kaplan-Meier survival probabilities for MOS 0161 (Administrative Postal Clerk). The sample size for the MOS is much larger than MOS 7372, which is reflected in the narrow confidence boundaries. Although the MOS is much larger in sample size than MOS 7372, the pattern of estimates is similar.

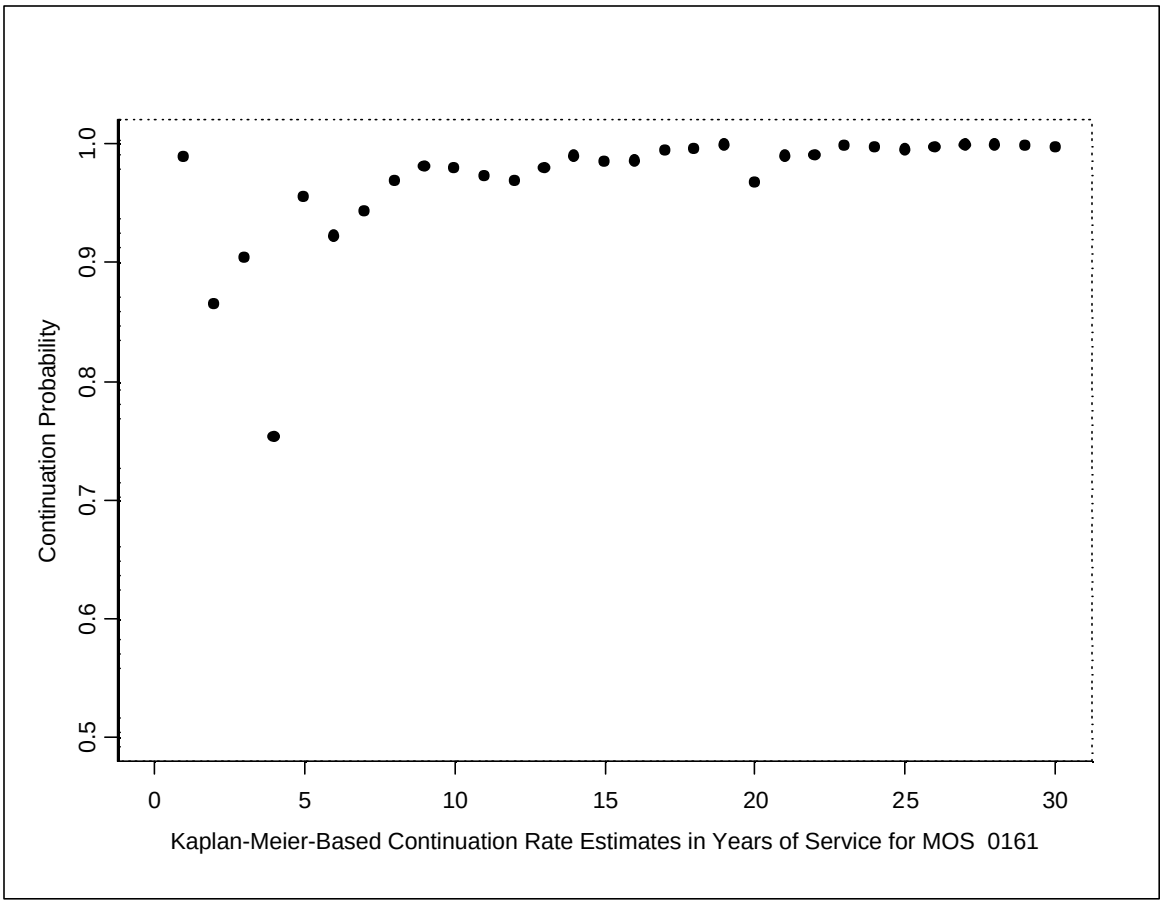

Figure 8. MOS 0161 Continuation Rate Estimates

Estimates for MOS 0161's continuation rates display similar characteristics to the estimates for MOS 7372. Both MOSs show noticeable decreases at yos eight and yos twenty.

Career progression MOSs which are supplied from Marines in "feeder" MOSs show essentially the same characteristics (Figures 9 and 10) with probability dips occurring when a Marine's contract is most likely to expire. MOS 0193 (Administrative Chief) is fed by MOSs 0121 and 0151. Since the lowest rank in MOS 0193 is E-6, and a Marine does not become eligible for promotion to E-6 until he has four years of service, the probabilities before four years of service should be undefined. The nature of the Kaplan-Meier estimator, and errors in the data that are discussed later make these "probabilities" close to one. The survivor probability starts dropping off after yos eight, which is a reasonable year for a Marine to pick up the rank of E-6. There is a pronounced fall in the minimum retirement transition period from year twenty to twenty-one. The tight confidence interval reflects the large sample size for this MOS.

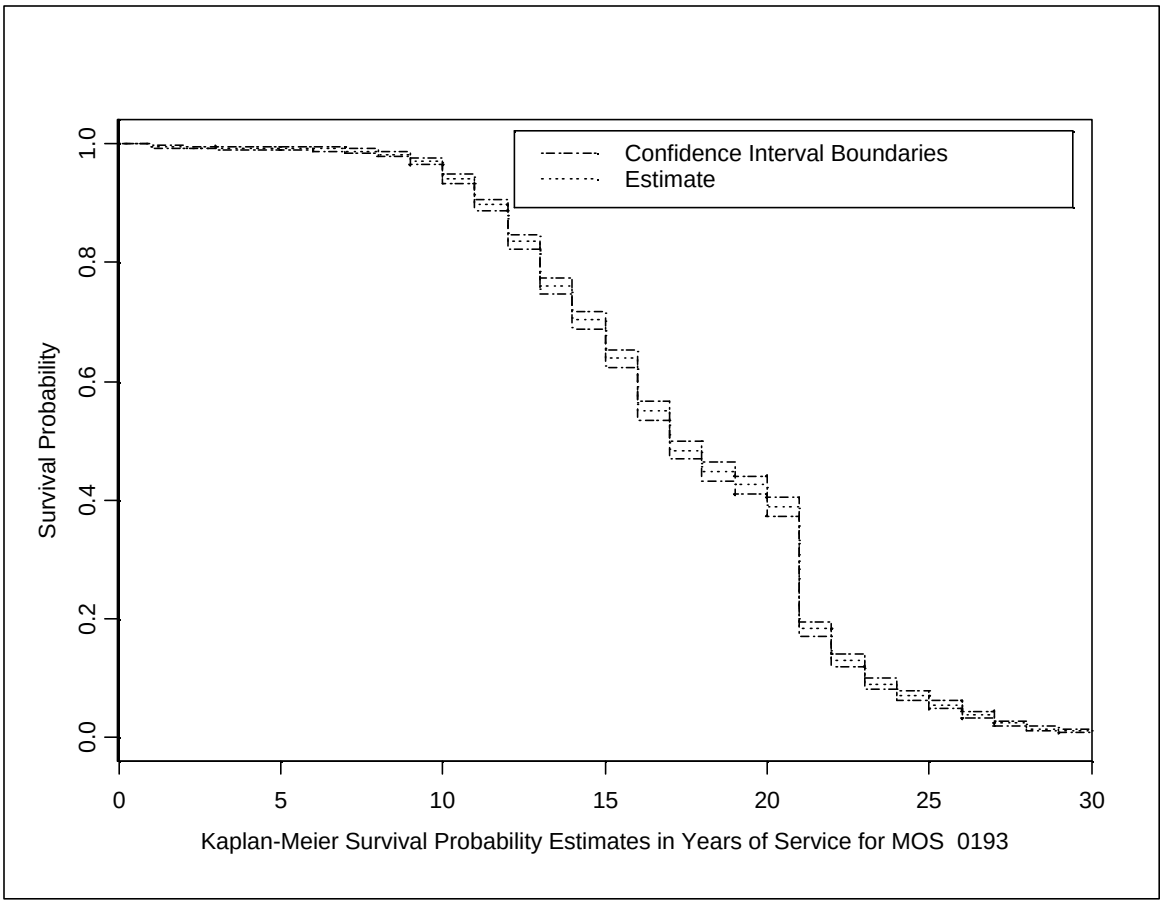

Figure 9. MOS 0193 Survival Probability Estimates

"Survival probabilities" stay close to one in MOS 0193 (Administrative Chief) until the MOS has Marines in it. This occurs at yos eight, which is a reasonable year for a Marine to be promoted to E-6, the lowest rank possible in this MOS.

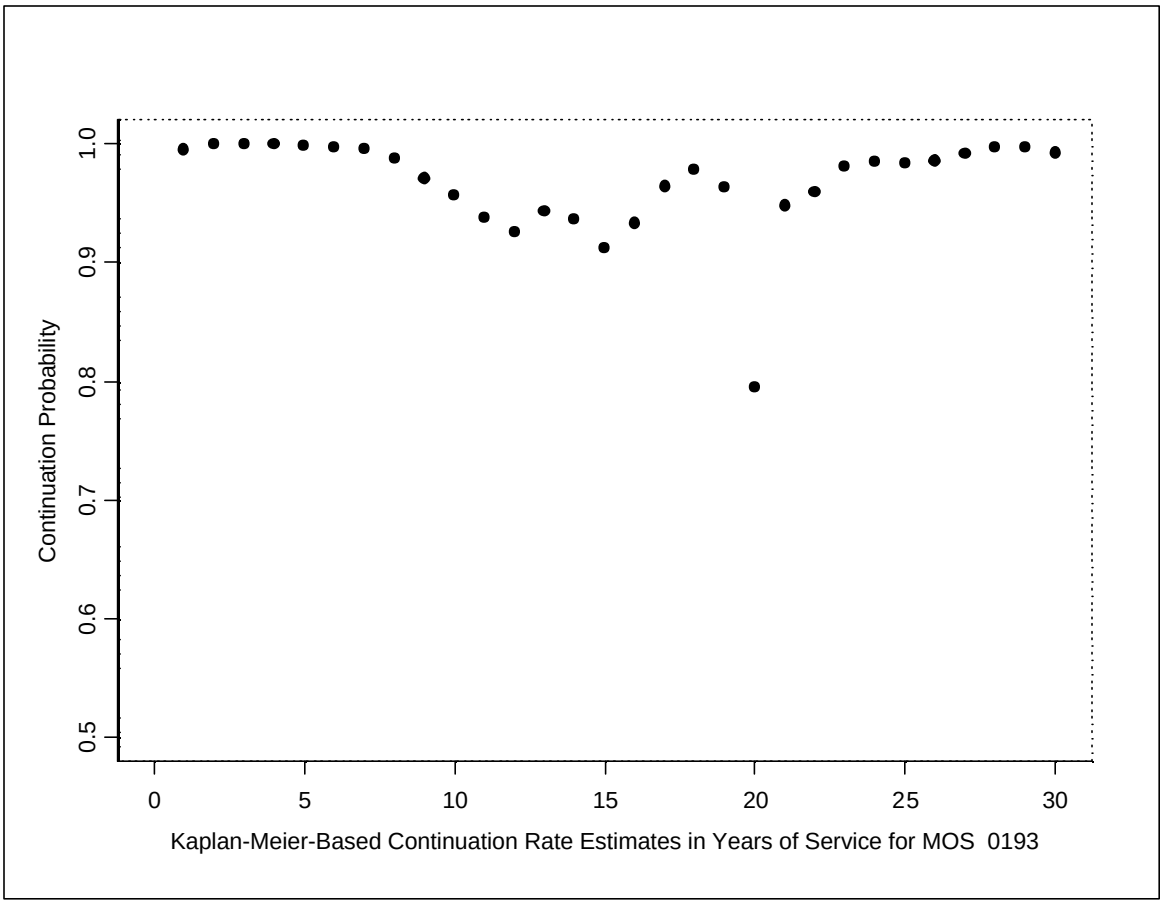

Figure 10. MOS 0193 Continuation Rate Estimates

Continuation rates for MOS 0193 stay close to one, until yos eight. (Estimates below yos eight should probably be ignored since this MOS will have few Marines in it with yos less than eight.) The probability returns to values close to one at eighteen years of service. Eighteen years of service is also the point where the Marine Corps usually grants retirement benefits.

F. EXAMINING THE DATA

This section examines the data that the survival and continuation estimates are computed from.

A summary of the S-Plus Kaplan-Meier survival estimates in Table 3 for MOS 0121 (Personnel Clerk) shows standard errors of less than 1% for each of the estimates under the column label "survival. There are two clearly erroneous data points of 99 years of service, under the column labeled "time." These errors show an error rate for the MOS of less than one for every 2000 data points and are not important. The conditional nature

of the Kaplan-Meier estimator should keep these errors from biasing the lower-level estimates to any significant degree.

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
0	4539	14	0.996916	0.000823	0.995304	0.99853
1	4525	114	0.971800	0.002457	0.966996	0.97663
2	4411	281	0.909892	0.004250	0.901600	0.91826
3	4130	919	0.707425	0.006753	0.694312	0.72078
4	3211	762	0.539546	0.007398	0.525239	0.55424
5	2449	1389	0.233532	0.006280	0.221542	0.24617
6	1060	193	0.191011	0.005835	0.179911	0.20280
7	867	350	0.113902	0.004715	0.105025	0.12353
8	517	189	0.072263	0.003843	0.065109	0.08020
9	328	92	0.051994	0.003295	0.045920	0.05887
10	236	68	0.037013	0.002802	0.031908	0.04293
11	168	53	0.025336	0.002332	0.021153	0.03035
12	115	39	0.016744	0.001904	0.013398	0.02093
13	76	34	0.009253	0.001421	0.006848	0.01250
14	42	28	0.003084	0.000823	0.001828	0.00520
15	14	9	0.001102	0.000492	0.000459	0.00265
16	5	1	0.000881	0.000440	0.000331	0.00235
17	4	1	0.000661	0.000381	0.000213	0.00205
20	3	1	0.000441	0.000312	0.000110	0.00176
99	2	2	0.000000	NA	NA	NA

Table 3. MOS 0121 Survival Probability Estimates

MOS 0121 (Personnel Clerk) Kaplan-Meier estimates, and the data they're based on. The "n.events" column provides the number of samples used for the estimators. The total number of samples for MOS 0121 is 4539. The "time" column reports the years of service that each n.risk sample group contained. The two "n.events" with 99 yos are obvious errors. The "survival" column lists the survival probability for a particular year of service.

Table 3 also shows seventy data points that extend beyond thirteen years of service. The rank structure defined by MCO P1200.7 specifies the ranks of E-1 to E-5 for MOS 0121. A Sergeant cannot stay in longer than 13 years because of enlisted career force controls. The forced separation at thirteen years might have been waived for these Marines; or the rank structure might have included higher ranks during the data collection period; or the Marines could have been reduced from a higher rank and assigned to MOS 0121 before they were separated; or policy changes during the period that data was collected could have affected the allowed length of service.

The S-Plus Kaplan-Meier survival estimates in Table 4 for MOS 0151 show a similar pattern to MOS 0121. Three data points out of 9838 are at 99 years of service. There are 409 other points out of 9838 that extend past thirteen years of service. Also the

years of service for this data set extend to 34 years. Actual policies over the ten-year period in which this data was collected were different than the current stated policy of not allowing Marines in MOS 0151 to continue beyond 13 years of service, or the policies were waived.

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
0	9838	16	0.99837	0.000406	0.997578	0.99917
1	9822	203	0.97774	0.001487	0.974828	0.98066
2	9619	656	0.91106	0.002870	0.905452	0.91670
3	8963	1427	0.76601	0.004268	0.757689	0.77442
4	7536	1701	0.59311	0.004953	0.583480	0.60290
5	5835	2871	0.30128	0.004626	0.292349	0.31048
6	2964	418	0.25879	0.004416	0.250281	0.26759
7	2546	906	0.16670	0.003758	0.159496	0.17423
8	1640	527	0.11313	0.003194	0.107044	0.11957
9	1113	321	0.08050	0.002743	0.075304	0.08606
10	792	214	0.05875	0.002371	0.054284	0.06359
11	578	189	0.03954	0.001965	0.035871	0.04359
12	389	113	0.02805	0.001665	0.024974	0.03151
13	276	135	0.01433	0.001198	0.012166	0.01688
14	141	82	0.00600	0.000778	0.004650	0.00773
15	59	16	0.00437	0.000665	0.003244	0.00589
16	43	14	0.00295	0.000547	0.002050	0.00424
17	29	7	0.00224	0.000476	0.001473	0.00339
18	22	1	0.00213	0.000465	0.001392	0.00327
19	21	3	0.00183	0.000431	0.001153	0.00290
20	18	2	0.00163	0.000406	0.000997	0.00265
21	16	5	0.00112	0.000337	0.000619	0.00202
22	11	1	0.00102	0.000321	0.000547	0.00189
23	10	1	0.000915	0.000305	0.0004761	0.001758
24	9	1	0.000813	0.000287	0.0004068	0.001626
26	8	1	0.000712	0.000269	0.0003393	0.001492
31	7	1	0.000610	0.000249	0.0002741	0.001357
32	6	1	0.000508	0.000227	0.0002116	0.001221
33	5	1	0.000407	0.000203	0.0001526	0.001083
34	4	1	0.000305	0.000176	0.0000984	0.000945
99	3	3	0.000000	NA	NA	NA

Table 4. MOS 0151 Survival Probability Estimates

MOS 0151 data has twice as many samples as MOS 0121. There are three samples with 99 years of service, a common error found throughout the data, indicating systemic problems.

MOSs 0121 and 0151 data sets show that the highest numbers of Marines depart from the service between yos three and yos five which is reasonable given that the usual contract is for four years.

Table 5 shows the S-Plus Kaplan-Meier survival estimates for MOS 7372 (KC-130 Navigator). Table 5 shows a pattern similar to MOS 0151. MOS 7372 is much

smaller, which is reflected by the 149 data points for the ten-year period studied. There is only one event at thirty-one years of service. There are no "99 years of service" errors. The standard errors for the estimates are higher for almost every data point, as expected. MOS 7372 differs from MOSs 0151 and 0121 because it does not feed into a career progression MOS. Marines from MOS 7372 stay in the MOS unless they separate. The window of departures for MOS 7372 is four to six years, rather than three to five years for MOSs 0121 and MOS 0151. The total training time for an MOS 0121 Marine is 64 days and the training time for MOS 0151 is 51 days. Total training time for MOS 7372 is 370 days. It is reasonable to assume that a longer contract is required because of the longer training period, and that is responsible for the longer stay before separation. Standard errors for MOS 7372 peak at yos six and seven with a continuous decline after year six. There are seventeen departures at yos seventeen, with none at yos eighteen and yos nineteen. (As noted before, yos seventeen is the last year that a Marine departs before crossing into the eighteenth year of service where current policies state that the Marine Corps must let a Marine continue to his twentieth year for retirement.)

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
1	149	1	0.99329	0.00669	0.980265	1.0000
2	148	2	0.97987	0.01151	0.957570	1.0000
3	146	4	0.95302	0.01733	0.919643	0.9876
4	142	17	0.83893	0.03011	0.781931	0.9001
5	125	27	0.65772	0.03887	0.585780	0.7385
6	98	20	0.52349	0.04092	0.449136	0.6102
7	78	12	0.44295	0.04069	0.369963	0.5303
8	66	10	0.37584	0.03968	0.305589	0.4622
9	56	7	0.32886	0.03849	0.261451	0.4136
10	49	6	0.28859	0.03712	0.224283	0.3713
11	43	7	0.24161	0.03507	0.181790	0.3211
12	36	4	0.21477	0.03364	0.157988	0.2919
13	32	4	0.18792	0.03200	0.134589	0.2624
14	28	8	0.13423	0.02793	0.089278	0.2018
15	20	4	0.10738	0.02536	0.067590	0.1706
17	16	1	0.10067	0.02465	0.062299	0.1627
20	15	1	0.09396	0.02390	0.057069	0.1547
21	14	7	0.04698	0.01733	0.022795	0.0968
22	7	1	0.04027	0.01611	0.018388	0.0882
23	6	1	0.03356	0.01475	0.014176	0.0794
24	5	1	0.02685	0.01324	0.010210	0.0706
25	4	2	0.01342	0.00943	0.003388	0.0532
27	2	1	0.00671	0.00669	0.000952	0.0473
31	1	1	0	NA	NA	NA

Table 5. MOS 7372 Survival Probability Estimates

Longer training length results in longer contract time (compared to MOSs 0121 and 0151) and shifts the bulk of discharges from a time window of three to five years of service to four to six years of service. There are no "99 year errors" in this data, so the systemic problem observed earlier with such errors may be limited to MOSs that restrict ranks from E-3 to E-5, like MOSs 0121 and 0151.

The S-Plus Kaplan-Meier survival estimates in Table 6 for MOS 0161 (Postal Clerk) reveal what appears to be a combination of traits from the administrative MOSs and the navigation MOS. The length of service pattern is the same, with a small number of departures at 31 years. The majority of departures are between three and five years of service, with a small drop at four years, similar to MOSs 0121 and 0151. A smaller training time of 52 days explains why the departure window starts and ends earlier than MOS 7372. The standard error for MOS 0161 peaks at year six, and displays the same continuous drop after year six as in MOS 7372. Another similarity to the distribution of the 7372 MOS is the drop-off in separations between years seventeen and twenty-one. MOS 0161 has ranks E-1 through E-9, like MOS 7372. As with the data for MOS 7372, there are no samples with 99 years of service.

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
0	962	1	0.9990	0.00104	0.9969	1.0000
1	961	10	0.9886	0.00343	0.9819	0.9953
2	951	52	0.9345	0.00798	0.9190	0.9503
3	899	130	0.7994	0.01291	0.7745	0.8251
4	769	92	0.7037	0.01472	0.6755	0.7332
5	677	238	0.4563	0.01606	0.4259	0.4889
6	439	43	0.4116	0.01587	0.3817	0.4439
7	396	75	0.3337	0.01520	0.3052	0.3648
8	321	55	0.2765	0.01442	0.2496	0.3063
9	266	30	0.2453	0.01387	0.2196	0.2741
10	236	19	0.2256	0.01348	0.2006	0.2536
11	217	20	0.2048	0.01301	0.1808	0.2319
12	197	26	0.1778	0.01233	0.1552	0.2036
13	171	30	0.1466	0.01140	0.1258	0.1707
14	141	20	0.1258	0.01069	0.1065	0.1486
15	121	10	0.1154	0.01030	0.0969	0.1374
16	111	15	0.0998	0.00966	0.0825	0.1206
17	96	14	0.0852	0.00900	0.0693	0.1048
18	82	6	0.0790	0.00870	0.0637	0.0980
19	76	4	0.0748	0.00848	0.0599	0.0935
20	72	1	0.0738	0.00843	0.0590	0.0923
21	71	32	0.0405	0.00636	0.0298	0.0551
22	39	10	0.0301	0.00551	0.0211	0.0431
23	29	9	0.02079	0.00460	0.01347	0.03208
24	20	2	0.01871	0.00437	0.01184	0.02957
25	18	3	0.01559	0.00399	0.00944	0.02576
26	15	5	0.01040	0.00327	0.00561	0.01926
27	10	3	0.00728	0.00274	0.00348	0.01522
28	7	1	0.00624	0.00254	0.00281	0.01385
29	6	1	0.00520	0.00232	0.00217	0.01246
30	5	2	0.00312	0.00180	0.00101	0.00965
31	3	3	0.00000	NA	NA	NA

Table 6. MOS 0161 Survival Probability Estimates

MOS 0161 with ranks of E-1 to E-9 contains no samples with 99 years of service. Like MOSs 0121 and 0151 the majority of discharges occur between at three and five years of service.

The S-Plus Kaplan-Meier survival estimates in Table 7 for MOS 0193 (Administrative Chief) reveals possible errors that differ from the MOSs previously discussed. Separation events are recorded for Marines with less than 4 years of service. The minimum rank for this MOS is E-6 and the minimum time in service for E-6 is four years. The nineteen events where Marines departed the service with one year of service are problematic; the conditional nature of the Kaplan-Meier lets these observations affect the survival estimators beyond one year of service. The large number of samples makes the effect small (.9923 probability of survival from year zero to year four rather than a reasonable probability of one). However, the survival rates carry down through later

years; if the twenty-eight Marines who separated before year four are erroneous data points the model will produce attrition estimates that are higher than they should be.

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
0	3905	1	0.9997	0.000256	0.9992	1.0000
1	3904	19	0.9949	0.001142	0.9926	0.9971
2	3885	5	0.9936	0.001276	0.9911	0.9961
3	3880	3	0.9928	0.001350	0.9902	0.9955
5	3877	2	0.9923	0.001397	0.9896	0.9951
6	3875	5	0.9910	0.001508	0.9881	0.9940
7	3870	13	0.9877	0.001763	0.9843	0.9912
8	3857	19	0.9828	0.002078	0.9788	0.9869
9	3838	49	0.9703	0.002717	0.9650	0.9756
10	3789	115	0.9408	0.003775	0.9335	0.9483
11	3674	169	0.8976	0.004852	0.8881	0.9071
12	3505	244	0.8351	0.005939	0.8235	0.8468
13	3261	292	0.7603	0.006831	0.7470	0.7738
14	2969	224	0.7029	0.007313	0.6888	0.7174
15	2745	251	0.6387	0.007687	0.6238	0.6539
16	2494	343	0.5508	0.007960	0.5355	0.5667
17	2151	262	0.4837	0.007997	0.4683	0.4997
18	1889	141	0.4476	0.007957	0.4323	0.4635
19	1748	87	0.4254	0.007912	0.4101	0.4411
20	1661	143	0.3887	0.007801	0.3737	0.4043
21	1518	803	0.1831	0.006189	0.1714	0.1956
22	715	204	0.1309	0.005397	0.1207	0.1419
23	511	159	0.0901	0.004583	0.0816	0.0996
24	352	77	0.070423	0.004094	0.0628380	0.07892
25	275	61	0.054802	0.003642	0.0481086	0.06243
26	214	65	0.038156	0.003066	0.0325968	0.04466
27	149	57	0.023560	0.002427	0.0192519	0.02883
28	92	34	0.014853	0.001936	0.0115046	0.01918
29	58	14	0.011268	0.001689	0.0083991	0.01512
30	44	11	0.008451	0.001465	0.0060165	0.01187
31	33	31	0.000512	0.000362	0.0001281	0.00205
32	2	1	0.000256	0.000256	0.0000361	0.00182
33	1	1	0.000000	NA	NA	NA

Table 7. MOS 0193 Survival Probability Estimates

MOS 0193 (Administrative Chief) data samples and their corresponding survival probabilities show errors at the lower years of service. There are 28 samples with less than four years of service; Marines should not be eligible for this MOS until they have four years of service or more.

The highest standard error encountered in the MOS 0193 survival estimates is .007997 in yos seventeen. 262 Marines separate in year 17; then separations drop to 141 and 87 in the following two years. In the twentieth year, separations rise to 143 and peak at 803 separations at yos 21. There are only two data points past yos 31. The indicators for this data set point to many errors at the beginning years of the data set and few at the end. The difference in the location of the standard error peak between MOS 0193 and

MOS 0161 is attributable to the career-track nature of MOS 0193. Fewer "death" observations at the lower years of service in relation to the total number of Marines in the data reduce the variance estimate.

The S-Plus Kaplan-Meier survival estimates in Table 8 for MOS 0369, (Infantry Platoon Sergeant) show a similar pattern to the MOS 0193 estimates. Career progression MOSs 0193 and 0369 have vastly different feeder MOSs and job duties but the rank structure of E-6 to E-9 is identical. There are twenty-six records for Marines who departed in yos one, indicative of systemic data errors in both career progression MOSs. After one year of service the separations decrease until rising at yos seven. Once again, the highest standard errors are encountered at yos seventeen. The highest number of separations is at twenty-one years, the same point as in MOS 0193.

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
1	4871	26	0.9947	0.00104	0.9926	0.9967
2	4845	3	0.9940	0.00110	0.9919	0.9962
3	4842	2	0.9936	0.00114	0.9914	0.9959
4	4840	5	0.9926	0.00123	0.9902	0.9950
5	4835	2	0.9922	0.00126	0.9897	0.9947
6	4833	7	0.9908	0.00137	0.9881	0.9935
7	4826	23	0.9860	0.00168	0.9828	0.9893
8	4803	39	0.9780	0.00210	0.9739	0.9822
9	4764	80	0.9616	0.00275	0.9562	0.9670
10	4684	144	0.9320	0.00361	0.9250	0.9391
11	4540	212	0.8885	0.00451	0.8797	0.8974
12	4328	312	0.8245	0.00545	0.8139	0.8352
13	4016	386	0.7452	0.00624	0.7331	0.7576
14	3630	244	0.6951	0.00660	0.6823	0.7082
15	3386	265	0.6407	0.00687	0.6274	0.6543
16	3121	466	0.5451	0.00713	0.5313	0.5592
17	2655	439	0.4549	0.00713	0.4412	0.4691
18	2216	217	0.4104	0.00705	0.3968	0.4244
19	1999	98	0.3903	0.00699	0.3768	0.4042
20	1901	263	0.3363	0.00677	0.3233	0.3498
21	1638	965	0.1382	0.00494	0.1288	0.1482
22	673	196	0.0979	0.00426	0.0899	0.1066
23	477	152	0.0667	0.00358	0.0601	0.0741
24	325	96	0.047013	0.003033	0.0414292	0.05335
25	229	34	0.040033	0.002809	0.0348894	0.04593
26	195	37	0.032437	0.002538	0.0278246	0.03781
27	158	50	0.022172	0.002110	0.0183997	0.02672
28	108	28	0.016424	0.001821	0.0132157	0.02041
29	80	12	0.013960	0.001681	0.0110253	0.01768
30	68	26	0.008622	0.001325	0.0063805	0.01165
31	42	40	0.000411	0.000290	0.0001027	0.00164
33	2	1	0.000205	0.000205	0.0000289	0.00146
34	1	1	0.000000	NA	NA	NA

Table 8. MOS 0369 Survival Probability Estimates

MOS 0369 survival estimates show a similar problem to MOS 0193 with events before four years of service. Most of the events before yos four occur at yos one. This indicates a systemic error for career progression MOS data.

The errors in the data for the MOSs examined lead to the conclusion that systemic errors in the Marine Corps data need to be investigated and the data should be cleansed if possible. Career progression MOSs that have Marines recorded as departing the service at one year of service, or feeder MOSs that have Marines continuing past service limits, were found in every sample set. There are also incidences of samples containing Marines who departed at 99 years of service. The conditional nature of the Kaplan-Meier estimator prevents the samples with errors in latter years from biasing previous estimates upwards for earlier years. However, if these samples represent Marines with misreported

years of service, then the computed survival estimates will be higher than they should be because the Marines should have shown up in the data somewhere in the earlier years.

V. RESULTS

This chapter presents MTYP's solutions for occfields 01 (Personnel Administration), 02 (Intelligence), and 03 (Infantry). Three MTYP occfield models are chosen out of the forty constructed for the sake of brevity. These results are compared with results from EAM and FTAP; STAP results are not available. Time limitations prohibit a thorough examination of all aspects of MTYP but it seems to perform well as an accessions forecasting tool during limited comparisons.

A. COMPUTER IMPLEMENTATION

MTYP is implemented in the optimization software package GAMS (General Algebraic Modeling System), revision 117 (GAMS 1997a) using the CPLEX version 6.6.6 solver. MTYP is run on a 2 GHz Pentium IV personal computer, with 1.05 GBytes of RAM. MTYP populated with data for occfield 0X, is denoted as MTYP0X.

MTYP01 consists of 13,155 equations, 42,118 variables, and 346,625 non-zero elements when initialized with data for 8622 Personnel Administration Marines from the March 2001 database. There are four primary (non-training) MOSs and two career progression promotions in MTYP01 (MOS 0121 to 0193 and MOS 0151 to 0193). MTYP01 solves in 3.82 minutes. The solution deviates from fspggar targets by only 8 Marines total, over the 30-year time horizon.

MTYP02 consists of 20,566 equations, 71,414 variables, and 704,130 non-zero elements when initialized with data from 1757 Intelligence Field Marines from the March 2001 database. There are six primary MOSs and five career progression promotions in MTYP02 (MOSs 0211, 0231, 0241, 0251, and 0261 feed into MOS 0291). MTYP02 solves in 29.1 minutes. The solution deviates from fspggar targets by 48 Marines total over the 30-year horizon.

MTYP03 consists of 22,987 equations, 65,885 variables, and 388,679 non-zero elements when initialized with data from 24,958 Infantry Marines from the March 2001 database. There are eight primary MOSs and seven career progression promotions in

MTYP03 (MOSs 0311, 0313, 0321, 0331, 0341, 0351 and 0352 feed into MOS 0369). MTYP03 solves in 16.9 minutes and deviates from fspggar targets by 408 Marines total over the 30-year horizon.

B. MTYP, EAM, AND FTAP ACCESSIONS

This section compares the solutions from MTYP, EAM and FTAP. A direct comparison is not possible because EAM and FTAP use an aggregated rank methodology for calculating cohort strengths.

EAM accessions are modeled using a discrete-time Markov process over a four-year time horizon. An aggregate fspggar target for ranks E-3 (Lance Corporal) and E-4 (Corporal) is used. The aggregated target number drives an estimate of the initial number of Marines input into an MOS each year. An accession number for every MOS is computed from the target; this is the number of Marines who will be assigned the MOS (Figure 11).

MTYP models accessions using the correct non-aggregated targets. Promotions to E-4 are separate, but affect accessions as the E-4 promotions deplete the supply of E-3s. Promotions to E-5 deplete the E-4 cohort, so more E-3s must be promoted to compensate.

Coefficient Matrix: PMOS 0121													
	n0	n1	n2	n3	n4	R	RHS					Solution:	
Equa 1	1	0	0	0	0	-1	0	-0.8243	-0.5791	-0	0.3	728	
Equa 2	-0.947	1	0	0	0	0	0	-0.7802	-0.5481	-0	0.3	689	
Equa 3	0	-0.92	1	0	0	0	0	0.2838	-0.5031	-0	0.3	633	
Equa 4	0	0	-0.91	1	0	0	0	0.2571	0.5444	-0	0.2	573	
Equa 5	0	0	0	-0.93	1	0	0	0.2393	0.5069	0.8	0.2	533	
Equa 6	0	1	1	1	1	0	2428.55	-0.8243	-0.5791	-0	0.3	728	

Figure 11. EAM Coefficient Matrix

EAM Excel coefficient matrix for MOS 0121 shows continuation rate coefficients and solutions for an aggregated target of 2429 Marines. The 0121 Marines are an aggregation of E-3s and E-4s. The aggregated target number 2429 is sought by changing the initial number of Marines (728) under solution until the four rows under the initial number sum to the target. The first five rows under the solution column are the initial cohort strength and the subsequent estimated cohort strengths after yos one to four. The aggregated targets used here assume that there will be no promotions to E-5 in the first four years of service. This assumption is not entirely valid, since the Marine database in 2001 reports nine E-5s in MOS 0121 with less than five years of service.

Year	Rank	MOS	Marines	tgtdev	% off	Accessions	Promotions in	Promotions out
2001	E3	121	1767	207	13	0	0	0
2002	E3	121	1624	64	4	728	0	352
2003	E3	121	1554	0	0	801	0	317
2004	E3	121	1553	0	0	807	0	331
2005	E3	121	1556	0	0	726	0	364
2006	E3	121	1555	0	0	693	0	328
2007	E3	121	1555	0	0	762	0	319
2008	E3	121	1555	0	0	727	0	287
2009	E3	121	1555	0	0	799	0	316
2010	E3	121	1555	0	0	719	0	316
2011	E3	121	1555	0	0	749	0	293
2012	E3	121	1555	0	0	712	0	322

Figure 12. MTYP01 Output for 0121 E-3s

MTYP MOS 0121 E-3 accessions are not fixed, and depend on attrition and the number of Marines promoted out of the cohort to E-4. MTYP produces output for thirty-years into the future, while EAM only looks at the next four years. MTYP does not use an aggregated rank target like EAM; the target deviation number (in the "tgtdev" column) is based on fspggar's 0121 E-3 target.

The initial results using models based on occupational fields 01, 02 and 03 show predicted accession numbers consistently smaller than EAM's. Accession rates analyzed from the model were obtained from model years 2002-2010. Actual 2002-2006 EAM

accessions are used to compare with accession numbers for the model for 2002-2010. EAM accessions from 2006 are extended to 2010 for graphic symmetry.

Figure 13 compares the effect that different survivor estimators have on accession levels. Estimators that are not rank-stratified in MTYP cause accessions to differ the most from EAM accession levels. The use of rank-stratified estimators causes accession levels to deviate from EAM accessions slightly.

Samples used for the survivor analysis were examined after rank-stratification. Anomalies with unlikely rank and MOS combinations were found. For example, there are a number of samples with primary MOSs at ranks E-1 and E-2. This depletes fspggar targeted cohort strengths. For instance, an MOS 0121 E-3 who is reduced to E-2, and discharged causes a depletion of the targeted fspggar 0121 E-3 cohort. Previous survivor analysis in this study did not reflect the loss of such Marines from the available manpower pool. To fix this discrepancy, a duplicate sample set was created and adjusted from the original survivor data. The new data set incorporates a "rank-reduction methodology" that finds samples that were reduced in rank and discharged. Once found, these samples have their ranks changed to E-3, so that their attrition would be correctly reflected in accessions levels.

MTYP's use of rank-stratified estimators from the altered data set that incorporates a rank-reduction methodology causes MTYP's accession levels to closely track EAM accession levels. (See figure 13 again.) This is the case for all MOSs modeled in the 01 and 03 occupational fields.

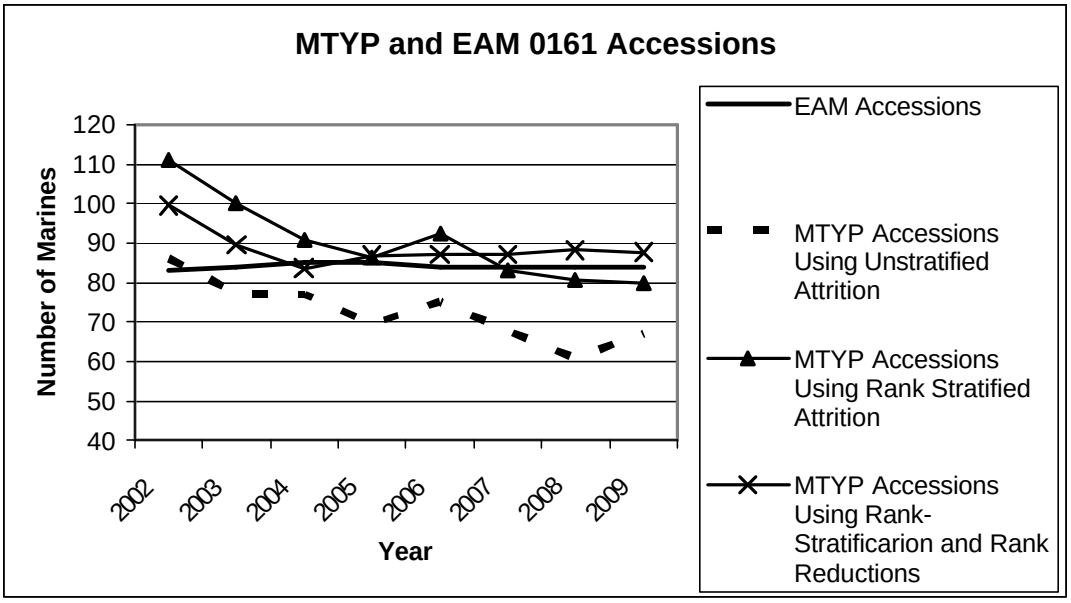

Figure 13. MOS 0161 Accessions

Comparison of rank, rank and reduction-conditioned, rank-stratified, and non-rank-stratified MTYP MOS 0161 accessions. MTYP using rank and reduction-conditioned attrition estimators run closest to EAM levels. Accessions are high in 2002 because the cohort was 10% under target levels during the initialization year of 2001.

C. MTYP, EAM, AND FTAP PROMOTIONS AND TARGETING

This section compares historic promotions from 1990-2000 to MTYP's forecast promotions for 2002-2010. Ideally, this comparison would be made over the same set of years, however MTYP initialization data for the years 1990-2000 is not available.

Promotions are not explicitly modeled in EAM or FTAP while MTYP's explicit modeling of promotions allows planners to set promotions to fill vacancies before they occur.

MTYP computes deviations from fspggar targets by rank, as they should be. EAM and FTAP cannot. Target deviations in EAM are computed by aggregating E-3s and E-4s. Target deviations in FTAP are computed by aggregating E-5s (Sergeants) through E-8s (Master Sergeants) who are in yos five to twenty.

MTYP suggests promotions in a deterministic model with full knowledge of what future attrition will be. This contrasts with historic promotions that occurred using EAM and FTAP in the context of a rolling horizon. For instance, in 2000 EAM and FTAP

were run to estimate accessions, and with those estimates accession and reenlistment decisions were made that implicitly affected promotion decisions made; time moved forward one year, actual attrition was observed, and new promotions were decided given the this new information and so on. For a proper comparison of MTYP to EAM and FTAP, MTYP should be run in a simulated rolling horizon.

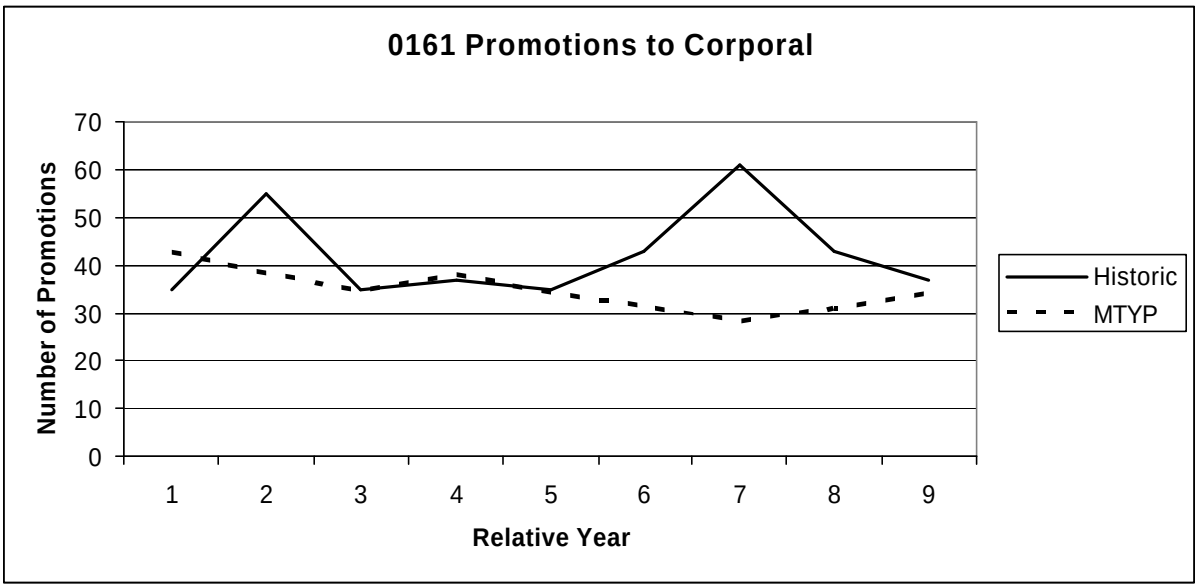

Figure 14. MOS 0161 Corporal Promotions

A comparison of historic MOS 0161 Corporal (E-4) promotions from 1992-2000 compared with MTYP years 2002-2010. The actual promotion years and MTYP model years are shown for contrast. MTYP's promotion levels vary significantly less from year-to-year.

Figure 14 shows MOS 0161 promotions to E-4 for model years 2002-2010 compared with historic promotions from 1992-2000. The actual promotions vary by as much as 30% from year to year. MTYP's promotions are restricted to vary by at most 10% from year to year. MTYP's constraints to restrict changes in promotions from year-to-year are clearly effective.

Figure 14 also shows a lower total number of promotions for the time horizon considered. Variations from year to year are expected but the cumulative number for the eight-year period is 20% higher than MTYP's cumulative promotions for the same period. Low attrition estimates for MOS 0161 E-4s could be causing the difference.

Figure 15 compares MOS 0161 promotions to Sergeant (E-5). The wide variations in historic promotions make conclusions difficult. The maximum year-to-year variation in historic promotions was 60% in 1993-1994. MTYP's largest variation is 10%.

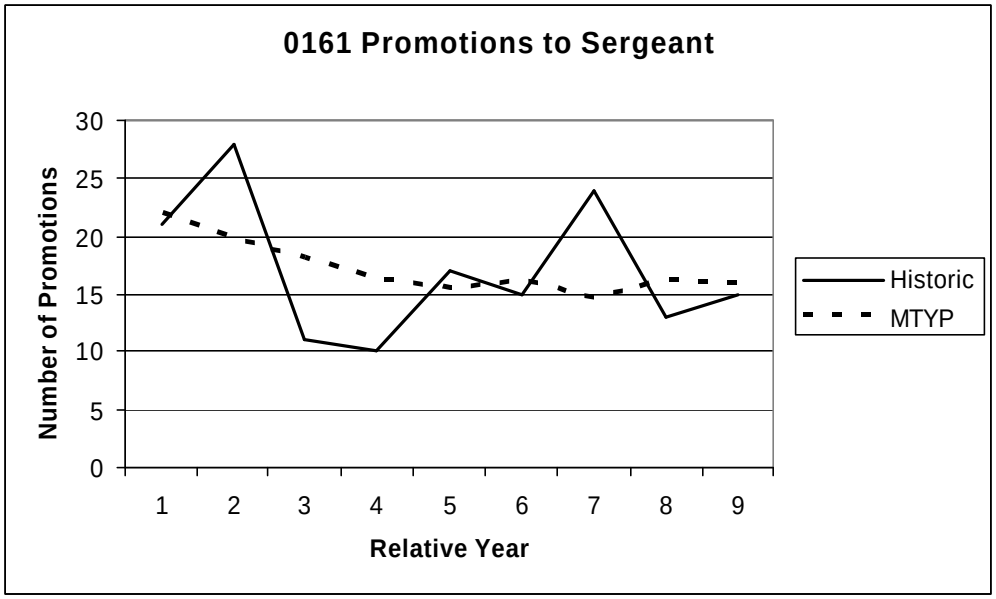

Figure 15. MOS 0161 Sergeant Promotions

MOS 0161 actual promotions from 1992-2000 and MTYP promotions from 2002-2010. The time periods are shown for contrast. MTYP promotion levels vary by 10%; the maximum variation in historic promotions was 60% in 1993-1994.

Figure 16 compares promotion levels to Staff Sergeant (E-6), the first rank in MOS 0161 where retirements are allowed. Variations in the number of promotions are larger than in ranks E-5 and below, which is a common theme in the historic E-6 to E-9 promotions. MTYP's MOS 0161 E-6 average promotion levels were 16% lower than historic averages over the 1992-2000 time horizon. This is not the usual case: in many of the MOSs examined, MTYP promotion levels for ranks E-6 to E-9 are greater than historic SNCO promotions during the 1992-2000 time horizon.

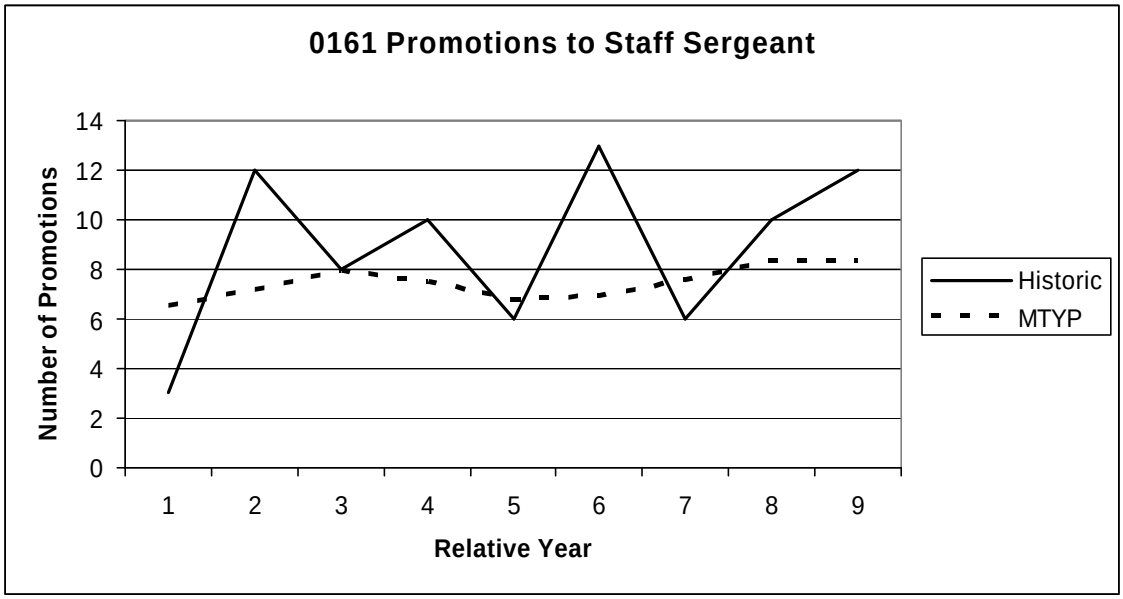

Figure 16. MOS 0161 Staff Sergeant Promotions

MOS 0161 actual promotions from 1992-2000 and MTYP promotions from 2002-2010. The time periods are shown for contrast. MTYP promotion levels vary by 10%; historic maximum variation was 75% in 1992-1993.

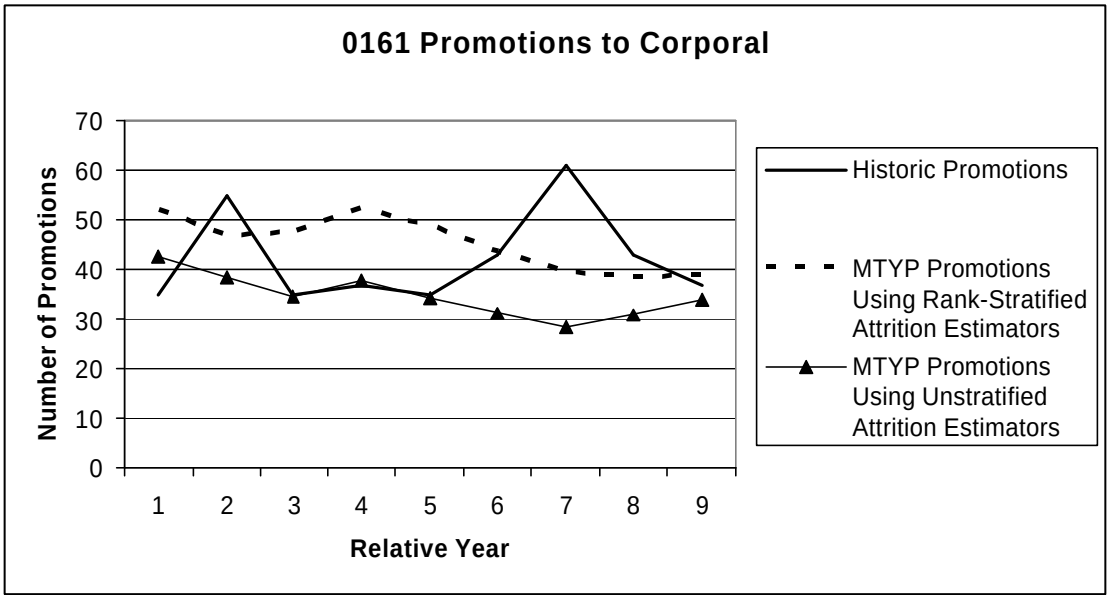

Figure 17. Rank-Stratified and Unstratified 0161 Corporal Promotions

MOS 0161 actual promotions from 1992-2000 and MTYP promotions from 2002-2010. The time periods are shown for contrast. MTYP uses rank-stratified and unstratified attrition estimators. MTYP promotion levels are higher by 20% when using rank-stratified attrition and track closer to actual promotion levels.

Figure 17 compares promotions to Corporal (E-4) when MTYP uses rank-stratified attrition estimators and unstratified attrition estimators. The graph shows that MTYP's promotion levels track closer to historic averages when using rank-stratified attrition estimators. Although MTYP promotion levels are higher for E-4s and E-5s when using rank-stratified attrition, they still fall below historic averages by 10-20%. MTYP promotion levels for ranks E-6 and above vary by 5-10% above and below historic averages.

Analysis of the attrition database does not yield any explicit clues about what the attrition rates might be for Marines who are reduced in rank from the E-4 or E-5 cohorts and then discharged. In contrast, reductions in rank from E-3, or reductions that affect the E-3 cohort are easily identified in the samples since they occur in the initial years of service. For example, an E-1 sample in MOS 0121 with two yos was probably reduced from rank E-3, and discharged. An E-3 in MOS 0121 with six yos could be a reduced E-4, a reduced E-5, or an E-3 with a six year contract who was never promoted to E-4. Reductions in the higher ranks of E-4 and E-5 are not as easy to identify. However, they should be identified and corrected if MTYP is to achieve the most accurate and useful results possible.

D. SUMMARY

MTYP solutions show accessions similar to EAM and average promotions similar to historic averages when rank-stratified estimators are used for attrition. MTYP may provide a good tool for downsizing an MOS: when the fspggar reduces an MOS target, MTYP could show the necessary reduction in accessions and promotions for that MOS. MTYP may also help reduce variability in the number of promotions. MTYP can provide the Marine Corps a unified tool to model promotions and their effect on accessions; there is no system for that now.

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VI. RECOMMENDATIONS AND CONCLUSIONS

This thesis has developed a linear program called MTYP (Marine Thirty-Year Plan) to guide the recruiting, training, promoting and discharging of an enlisted force of over 153,000 Marines. MTYP's advantages over current models are the ability to forecast accessions (recruits), promotions, and movement between military occupational specialties (MOSs) for a span of time that current models do not cover. Results show that MTYP may reduce year-to-year variation in promotions, it provides reasonable forecasts of accessions, and it shows the effects of downsizing. Further work is required to validate MTYP.

A. CONCLUSIONS

Direct comparisons between MTYP and the current models, Enlisted Accessions Model (EAM), First Term Alignment Plan (FTAP), and Subsequent Term Alignment Plan (STAP) are difficult since the current models do not incorporate the same features as MTYP. EAM estimates the number of recruits needed at the entry level of each MOS in order to meet demand after attrition reduces the number of Marines in their first four to five years of service. FTAP models the demand for Marines in a particular MOS as they enter their second contract, which usually comes between three and five years of service. STAP models demand for Marines entering subsequent contracts.

MTYP replaces these three models, covering all contract periods. MTYP explicitly models enlisted Marine recruiting, promotions, lateral moves, and forceouts over the time horizon covered by the three present models in a unified fashion. The current models handle these decisions in an ad hoc way, without optimization. MTYP shows reduced year-to-year variation in promotion levels compared to historical data.

The Marine Corps has systemic errors in its attrition database that affect attrition statistics. The errors consist of samples that contain years-of-service entries that cannot be correct. The database needs to be examined and the errors removed if possible. Attrition statistics need to incorporate cases where Marines are reduced in rank, and then

discharged. Rank-stratified attrition statistics based on samples containing Marines that were reduced in rank and discharged could be incorrect.

Key inputs to MTYP are estimated attrition rates. MTYP uses rates computed through Kaplan-Meier estimates of "survival probabilities." A survival probability corresponds to the probability that a Marine will stay in the Marine Corps from entry to a given year. A study of MTYP's predicted accessions and promotions show that accurate predictions require attrition estimates to be computed for individual ranks and years of service, not for years of service alone. That is, ranks must not be aggregated for the purposes of estimating attrition.

B. RECOMMENDATIONS

The actual value of MTYP compared to current methodology (EAM, FTAP, and STAP) can only be determined through a simulation study. MTYP will be used, like its competitors, in the context of a rolling time horizon and that use should be simulated. In particular, an initial time horizon of years 1-30 should be defined and MTYP run over that time horizon. Then, decisions from year two should be implemented and the time horizon moved forward to years 2-31. Actual attrition for that first year should be incorporated, and the model rerun. This should be repeated for, say ten years and 50 replications and results of MTYP compared to the other models operated in the same simulation environment.

MTYP incorporates constraints to reduce the year-to-year variations in promotions, but these constraints could cause problems. The Marine Corps promotes individuals when spaces become vacant due to attrition or promotion to a higher rank. If the number of promotions is bounded in some fashion—this is what MTYP does—then too many or too few promotions may take place. This issue needs to be studied in the simulation study described above, and these "promotion-variation constraints" relaxed if necessary.

If MTYP helps stabilize promotion levels throughout the Marine Corps, it will have a feedback effect and reduce attrition. It will be necessary to recalculate the

Kaplan-Meier-based attrition estimates every year to recalibrate the model to the new attrition statistics.

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APPENDIX A. MTYP SOLUTION GUIDE

The spreadsheet extract in Figure 18 shows a sample of the solution output from the 01 occfield model. GAMS outputs MTYP results in a .CSV format which can be opened with Excel without any formatting guidelines. The name of the file will indicate what occupational field the output models. In this case the name of the file is MTYPTOT01.CSV, indicating that the output is the total from the 01 field. The "year", "rank", and "MOS" columns are self-explanatory. The "Marines" column contains the number of Marines in that rank and MOS for the year, summing over the time in grade and years of service indices. The "tgtdev" column compares the "Marines" field with the fspggar target numbers. A reading of 10 in the "% off" column indicates that the ratio of tgtdev/fspggar is 10% off, This is not the ratio of "tgtdev" to "Marines." The "accessions" column contains accessions for the field, only active at the rank of E-3. The initial year of this model run is 2001. 2002 is when accession input is allowed, and 2003 is the first year that targeting becomes a factor in the calculation of target deviations. The "Accessions" column will read zero for the initializing year of the model.

The "Promotions in" column is self explanatory and is blank for E-3s, since that is the first rank the model is concerned with. The "Promotions out" column contains the promotions to the next rank, summed over years of service. Time in grade for all promotions is reset to zero. "Lat moves in" and "Lat moves out" are concerned with lateral moves into and out of a rank-MOS field. The "Forceout" column is self-explanatory. The "Pfed in" and "Pfed out" columns show the number of fed promotions between feeder and career progression MOSs. If an MOS allows promotion input by both feeder MOS and organic promotions then they are summed in the "Promotions in" column.

Year	Rank	MOS	Marines	tgtdev	% off	Accessions	Promotions in	Promotions out	Lat moves in	Lat moves out	Forceout	Pfed in	Pfed out
2001	E3	121	1767	207	13	0	0	0	0	0	0	0	0
2002	E3	121	1717	157	10	747	0	235	0	0	0	0	0
2003	E3	121	1554	0	0	821	0	259	0	0	0	0	0
2004	E3	121	1553	0	0	775	0	247	0	0	0	0	0
2005	E3	121	1556	0	0	698	0	271	0	0	0	0	0
2006	E3	121	1555	0	0	733	0	263	0	0	0	0	0
2007	E3	121	1555	0	0	753	0	289	0	0	0	0	0
2008	E3	121	1555	0	0	754	0	262	0	0	0	0	0
2009	E3	121	1555	0	0	703	0	289	0	0	0	0	0
2010	E3	121	1555	0	0	710	0	260	0	0	0	0	0
2011	E3	121	1555	0	0	749	0	286	0	0	0	0	0
2012	E3	121	1555	0	0	824	0	315	0	0	0	0	0
2013	E3	121	1555	0	0	741	0	322	0	0	0	0	0
2014	E3	121	1555	0	0	800	0	290	0	0	0	0	0
2015	E3	121	1555	0	0	720	0	292	0	0	0	0	0
2016	E3	121	1555	0	0	715	0	262	0	0	0	0	0

Figure 18. MTYP .CSV Output

MTYP LPs were modeled using GAMS, using a C-PLEX solver on a two Gigahertz Pentium IV Dell PWS 240, with one Gigabyte of RAM. The GAMS integrated developers environment was utilized under a Windows 2000 operating system. Completion times for the different occfield models varied, the average was twenty minutes. File output was directed into comma-separated value (.CSV) files that could be read and manipulated without import utilities directly into Excel.

APPENDIX B. S-PLUS CODE

The function `fill.in.MOS()` was written by thesis co-advisor Professor Sam Buttrey to take a two column matrix as an argument when calling the function and constructing a 1 *x* 30 vector. Data from the passed matrix is sent to the S-plus function `approx()`, which creates linear approximations for missing values based upon the surrounding data points. A 1 *x* 30 vector consisting of the continuation rate coefficients with the linear approximations between missing values is output.

```
fill.in.MOS <-
function(x.and.y)
{
# extracts year of service vector
   x <- x.and.y[, 1]
# extracts continuation rate vector
   y <- x.and.y[, 2]
# create new vector
   new.xs <- 1:30
# linear approximation of missing values into vector
   approx.thing <- approx(x, y, xout = 1:30)
   cbind(x = approx.thing$x, y = approx.thing$y)
}
```

The `bust()` function was written by Professor Sam Buttrey to take data that has been copied from the Marine attrition database file Surbust and changes the `paygrades` field in the database to account for reductions in rank.

```
bust <-
function(dat = Surbust)
{
   use <- is.element(dat$mos, mosCol[, 1])
   # Looks for valid MOS's that are
   # currently targeted
   pay <- dat$Paygrade
   bust.1 <- dat$Paygrade < 4 & dat$yos < 5
   pay[use & bust.1] <- 4
   #       Changes       paygrade       to       4       (E-3)       if
   # paygrade is less than 4 and yos less than 5
   bust.2 <- dat$Paygrade < 5 & dat$yos > 5 & dat$yos < 8
   pay[use & bust.2] <- 5
   # Changes paygrade to 5 (E-4) if paygrade is less than      # 5
   and yos between 5 and 8 (exclusive)
   bust.3 <- dat$Paygrade < 6 & dat$yos > 7 & dat$yos <  14
   pay[use & bust.3] <- 6
   bust.4 <- dat$Paygrade < 7 & dat$yos > 13 & dat$yos <       20
   pay[use & bust.4] <- 7
   pay
}
```

The S-plus script program `occfield()` takes data from the enlisted attrition databases conditioned on an MOS in the data matching current fspggar MOSs. The `occfield()` compiles the Kaplan-Meier based continuation rate estimators. Once the

estimators are compiled it writes the data into GAMS-readable data tables. There are 40 data tables written, one for each decomposed occupational field.

```
for (i in 1:length(occ$field)) {

   # creates file with filename based on occupational field
   filename <-
   paste("c:\\Enholm\\data\\test\\croestuff\\croe",unlist(occ$field[i])
   ,"d.dat", sep = "")
   cat("occfield",unlist(occ$field[i]))

   # Gams table headings
   tablename <- "TABLE  croe(rank,mos,yos)  continuation rate coefficient for
   mos in yos"
   write.table(tablename, file=filename, sep="\t", append = F,
   dimnames.write=F)
   write.table("", file=filename, sep="\t", append = T, dimnames.write=F)
   yearstring <-"               1        2       3       4       5       6
   7       8       9       10      11      12      13      14      15      16
   17      18      19      20      21      22      23      24      25      26
   27      28      29      30"
   write.table(yearstring, file=filename, sep="", append = T, dimnames.write=F)

   for (j in 1:length(rankmos$mos)) {

      # Look for mos's in occupational field
     if (unlist(occ$field[i]) == unlist(unpaste(rankmos$mos[j], sep = "",
   first = 1, width = 2)))  {
      cat(filename,"mos:  ", rankmos$mos[j], "  ranks: ", rankmos$ranks[j],
   "\n")
      temprm <- paste(rankmos$ranks[j],".", rankmos$mos[j], sep="")
      #if (length(Surbust[Surbust$mos == rankmos$mos[j],  ]$mos) > 0)  {
         tempmos <- rankmos$mos[j]
         if (is.element(rankmos$mos[j], mosswitch$new))  {   # checks for
   replacement mos's
               tempmos <- mosswitch[mosswitch$new == rankmos$mos[j],]$old
   #switches replacement mos
               ranks <- rankmos$ranks[j]
                if (nchar(ranks)==7) {
                  firstone <- as.integer(substring(ranks,3,3))
                   lastone <- as.integer(substring(ranks,6,6))
                   for (l in firstone:lastone) {
                      switchfunk(tempmos,rankmos$mos[j], j, l, filename)
                   }
                }


          }
          # Look for valid ranks for the chosen mos
          ranks <- rankmos$ranks[j]
          if (nchar(ranks)==7) {
                firstone <- as.integer(substring(ranks,3,3))
                lastone <- as.integer(substring(ranks,6,6))
                for (l in firstone:lastone) {
                   rankfunk(tempmos, j, l, filename)
                }
            }

      }
```

```
   }
   write.table(";", file=filename, sep="\t", append = T, dimnames.write=F)
}


rankfunk <-
function(tempmos, k, l, filename)
{


      temprm <- paste("E",l,".", tempmos, sep="")
      cat(temprm,"\n")
      mtyp.tmp <- summary(survfit(Surv(Surbust[Surbust$mos == tempmos &
   Surbust$Paygrade == l + 1,]$yos) ~ Surbust[Surbust$mos == tempmos &
   Surbust$Paygrade == l + 1,]$mos , data=Surbust[Surbust$mos == tempmos &
   Surbust$Paygrade == l + 1, ]))
      cat(mtyp.tmp, "\n")
      stemp <- cbind(mtyp.tmp$time, mtyp.tmp$surv)
      stemp[1,] <- c(1, 1-(1- mtyp.tmp$surv[2]))
      # Create croe coefficients from K-M survivor estimators
      for (m in 2:(length(mtyp.tmp$surv))) stemp[m,] <- c(mtyp.tmp$time[m], 1-
   (mtyp.tmp$surv[m]-mtyp.tmp$surv[m+1]))
      stemp[is.na(stemp)] _ 0
      # use the function fill.in.MOS to fill in missing yos with linear
   approximations
      ftemp <- fill.in.MOS(stemp)
      ftemp[is.na(ftemp[,2])] _ 0
      croetemp <- t(c(temprm, format.default(ftemp[,2], digits = 2, nsmall = 4,
   small.interval = 4)))
      croeline <-data.frame(croetemp)
      print(croeline)
      # Write the croe estimators to occfield file
      write.table(croeline, file=filename, sep="\t", append = T,
   dimnames.write=F)
      NULL

}
```

APPENDIX C. EXCEL MACRO CODE

Data in a comma-separated format was compiled for the project by the Defense Manpower Data Center West (DMDC West). The data consisted of current and historical cohort strengths, historical promotion rates, and discharge data. Data in a Microsoft Excel spreadsheet was also furnished by M&RA. The M&RA data consisted of fspggar target levels, and current accession levels. Visual Basic macros were imported directly into fspggar and EAM spreadsheets from HQMC. One macro fixed the accession variable $A_{r,\,m,\,y,\,g,\,t}$ for the first year of the model from the EAM data. Another macro was imported into the fspggar target level spreadsheet to create a GAMS-readable data table. MTYP uses the table to set the target levels for the cohorts.

The cohort attrition data was analyzed with the use of MathSoft's S-Plus statistical analysis software data import utility. Macros written by thesis co-advisor Professor Samuel Buttrey and the author analyzed the attrition data (Appendix B). Enlisted strength data was sorted into formatted cohort data with the use of Visual Basic macros written by the author. The formatted cohort strength data was written into a GAMS-readable data file that set the initial enlisted cohort levels for the first year of the planning horizon. The historical promotion rate data was used in its raw form to analyze and compare historical promotion rates with model-calculated promotion rates. Appendix E provides flow chart representations of the data construction and insertion points relative to the model architecture.

1. EXCEL MACRO `IMPORT()`

The Excel Macro `Import()` takes a comma-separated (.CSV) file and puts it into an Excel workbook. This macro is particularly useful for large .CSV files; it stops writing the data at line number 65535 in one worksheet, and then moves it to line 1 of the next worksheet. This macro was tailored to the Marine Corps enlisted database downloads; it creates three worksheets that contain the information for over 153,000 enlisted Marines. `Import()` was written to facilitate cohort summation work on the resulting worksheets. It is limited by a slow run time, over two hours on a Pentium II 400

MHz personal computer. `Import()` assumes that the current workbook has 3 worksheets in it.

```
Sub Import()
'
' Import Macro
' Macro recorded 8/16/2001 by jcenholm
'
' Keyboard Shortcut: Ctrl+Shift+I
'
CurrDir = ThisWorkbook.Path
CurrName = ThisWorkbook.Name
‘ Open database snapshot file
Fname = CurrDir & "\march 2001 snapshot.csv"
Open Fname For Input As #1
r = 0
c = 0
numSheets = 1
CurrLine = 0
Set ImpRange = ThisWorkbook.Sheets("Sheet" & numSheets).Range("A1")
‘ Suppresses Excel pop-up windows during execution
Application.ScreenUpdating = False
Do While Not EOF(1)
‘ Reset and go to next worksheet
   If CurrLine = 65635 Then
      r = 0
      c = 0
      numSheets = numSheets + 1
```

```
   CurrLine = 0
   Set ImpRange = _
      ThisWorkbook.Sheets("Sheet" & numSheets).Range("A1")
End If

CurrLine = CurrLine + 1
Line Input #1, data
Application.StatusBar = "Processing Line " & CurrLine
For i = 1 To Len(data)
   char = Mid(data, i, 1)
   If char = "," Then
     ‘Writes character string to cell
      ImpRange.Offset(r, c) = txt
      c = c + 1
      txt = ""
   Else
      If char <> Chr(34) Then _
         txt = txt & Mid(data, i, 1)

      If i = Len(data) Then
       ‘Writes character string to cell
         ImpRange.Offset(r, c) = txt
         c = c + 1
         txt = ""
      End If
   End If
Next i
c = 0
```

```
    Set ImpRange = ThisWorkbook.Sheets("Sheet" & numSheets).Range("A1")
    r = r + 1
  Loop
  Close #1
  Application.ScreenUpdating = True
  Application.StatusBar = False
  End Sub
```

2. EXCEL MACRO COUNT()

Count() takes a multi-dimensional variable called Efield and fills it with the number of Marines in a cohort. Count() uses the data imported by Import() to fill the Efield variables. The Efield declaration must be in the workbook's General declaration section. Count() is specialized to work with Marine Corps database column headings such as "Armed Forces Act Du Base Date" and "Permanent Grade."

```
  'Efield declaration
  Type Efield
      rank As String
      tig As Integer
      yos As Integer
      mos As String
      num As Integer
  End Type

  Sub count()
  '
  ' count Macro
  ' Macro recorded 8/23/2001 by jcenholm
  '
```

```
' Keyboard Shortcut: Ctrl+c
'
‘ Variable declarations
CurrDir = ThisWorkbook.Path
CurrName = ThisWorkbook.Name
Dim Field_names As String
Dim PmosPos As Integer
Dim ActDuDatePos As Integer
Dim RankPos As Integer
Dim RankDatePos As Integer
Dim DateNow As String
LastColumn = ThisWorkbook.Sheets("Sheet1").UsedRange.Columns.count
 lasti = LastColumn
 i = 1
 LastColumn = ThisWorkbook.Sheets("Sheet1").UsedRange.Columns.count
lasti = LastColumn
Dim ColRng As Range
 i = 1
 r = 0
 c = 0
 Set ColRng = Sheets("Sheet1").Range("A1")
 temp = ColRng.Value
 Do While (i <= lasti)
  ‘database column headings
   If (Trim(temp) = "Armed Forces Act Du Base Date") Then
     ActDuDatePos = i - 1
   End If
   If (Trim(temp) = "Permanent Grade") Then
```

```
      RankPos = i - 1
    End If
    If (Trim(temp) = "Present Rank Date") Then
      RankDatePos = i - 1
    End If
    If (Trim(temp) = "Primary Mos Code") Then
      PmosPos = i - 1
    End If
    c = c + 1
    temp = ColRng.Offset(r, c).Value
    i = i + 1
  Loop

Dim TempYos As Integer
Dim TempMos As String
Dim TempRank As String
Dim TempTig As Integer
Dim TempString As String
Dim ThisYear As Integer
ThisYear = 2001

r = 0
x = 1
Dim lastx As Integer
Dim tempx As Integer
Dim newOne As Boolean
newOne = False
lastx = 1
```

```
Dim E() As Efield
ReDim Preserve E(x)
E(x).num = 0
Set ColRng = Sheets("Sheet1").Range("A2")
LastRow = Sheets("Sheet1").UsedRange.Rows.count
TempString = Right(ColRng.Offset(r, ActDuDatePos).Value, 12)
TempString = Left(TempString, 4)
‘year of service calculation
TempYos = ThisYear - Val(TempString)
TempRank = Trim(ColRng.Offset(r, RankPos).Value)
TempString = Right(ColRng.Offset(r, RankDatePos).Value, 12)
TempString = Left(TempString, 4)
‘time in grade calculation
TempTig = ThisYear - Val(TempString)
TempMos = Trim(ColRng.Offset(r, PmosPos).Value)
If TempRank = "E1" Or TempRank = "E2" Then
   TempRank = "E3"
   TempTig = 0
End If
E(x).mos = TempMos
E(x).rank = TempRank
E(x).tig = TempTig
E(x).yos = TempYos
E(x).num = 1
ReDim Preserve E(lastx + 1)
lastx = 2
r = 1
```

```
For j = 1 To 3
   If j = 1 Then
      Set ColRng = Sheets("Sheet1").Range("A2")
      LastRow = LastRow - 1
   End If
   If j = 2 Then
      lastx = lastx - 1
      Set ColRng = Sheets("Sheet2").Range("A1")
      LastRow = Sheets("Sheet2").UsedRange.Rows.count
      r = 0
   End If
   If j = 3 Then
      Set ColRng = Sheets("Sheet3").Range("A1")
      LastRow = Sheets("Sheet3").UsedRange.Rows.count
      r = 0
   End If


   For i = 1 To LastRow
       TempString = Right(ColRng.Offset(r, ActDuDatePos).Value, 12)
       TempString = Left(TempString, 4)
       TempYos = ThisYear - Val(TempString)
       TempRank = Trim(ColRng.Offset(r, RankPos).Value)
       TempString = Right(ColRng.Offset(r, RankDatePos).Value, 12)
       TempString = Left(TempString, 4)
       TempTig = ThisYear - Val(TempString)
       TempMos = Trim(ColRng.Offset(r, PmosPos).Value)
       If (TempRank = "E1") Or (TempRank = "E2") Then
```

```
            TempRank = "E3"
            TempTig = 0
         End If
         r = r + 1


        ‘ Efield variable E initialization
         E(lastx).mos = TempMos
         E(lastx).rank = TempRank
         E(lastx).tig = TempTig
         E(lastx).yos = TempYos
         E(lastx).num = 1
         newOne = True
         For x = 1 To lastx – 1
            ‘ Efield variable E summation over cohorts
            If   ((E(x).mos   =   E(lastx).mos)   And   (E(x).rank   =
E(lastx).rank) And _
               (E(x).tig    =    E(lastx).tig)    And    (E(x).yos    =
E(lastx).yos)) Then
                E(x).num = E(x).num + 1
                newOne = False
             End If
         Next x
         If (newOne = True) Then
            lastx = lastx + 1
            ReDim Preserve E(lastx)
         End If
       Next i
     Next j
```

```
    ReDim Preserve E(lastx - 1)
    Sheets("mos").Select
    Cells.Select
    Selection.ClearContents
    Range("A1").Select
    'write column headings
    Worksheets("mos").Range("A1") = "MOS"
    Worksheets("mos").Range("B1") = "RANK"
    Worksheets("mos").Range("C1") = "TIG"
    Worksheets("mos").Range("D1") = "TIS"
    Worksheets("mos").Range("E1") = "Number"

    For x = 1 To lastx – 1
       'write cohort strengths
       Worksheets("mos").Range("A" & 1 + x) = E(x).mos
       Worksheets("mos").Range("B" & 1 + x) = E(x).rank
       Worksheets("mos").Range("C" & 1 + x) = E(x).tig
       Worksheets("mos").Range("D" & 1 + x) = E(x).yos
       Worksheets("mos").Range("E" & 1 + x) = E(x).num
    Next x
End Sub
```

3. EXCEL MACRO SETINITIAL()

SetInitial() takes the cohort values from the "mos" worksheet created by count() and writes it into forty text formatted GAMS data files. The values are written into MTYP's parameter *InitInv* which is used to initialize MTYP.

```
Sub SetInitial()
'
' SetInitial Macro
' Macro recorded 8/28/2001 by jcenholm
'
' Keyboard Shortcut: Ctrl+s
'
LastRow = Sheets("mos").UsedRange.Rows.count
LastRow = LastRow - 3
Dim InitialArray() ' array containing initial values
Dim AsOf, CurrDir
ReDim Preserve InitialArray(LastRow, 6)
AsOf = Now
CurrDir = ThisWorkbook.Path
Dim newMos As String
newMos = Sheets("mos").Range("A" & 2).Value
tempOc = Left(newMos, 2)
Ocrt = Right(newMos, 2)
MosArray = Array("01", "02", "03", "04", "06", "08", "11", "13",
"18", "21", "23", "26", "28", "30", "31", "33", "34", "35", "40",
"41", "43", "44", "46", "55", "57", "58", "59", "60", "61", "62",
"63", "64", "65", "66", "68", "70", "72", "73", "84", "84", "98",
"99")
' Open file and write data to it.
For occfield = 0 To 41
   Open CurrDir & "\Initial\Initial" & MosArray(occfield) & ".dat"
For Output As #1

' print Promotion bound table
```

```
Print #1, "* Initial Values for Model InitInv(rank, mos, tig, yos, t
= year)"
   Print #1,
   Dim k As Integer
   k = 0
   For rowpos = 2 To LastRow
       If Len(newMos) = 3 Then
          newMos = "0" & newMos
       End If


       If (MosArray(occfield) = tempOc And Ocrt <> "00" And
         Sheets("mos").Range("C" & rowpos).Value < 20 And
         Sheets("mos").Range("D" & rowpos).Value < 30) Then
             For j = 0 To 5
             If (j = 0) Then
                   Print #1, "InitInv('";
                   Print #1, Trim(Sheets("mos").Range("B" &
                         rowpos).Value);
                   Print #1, "','";
             End If
             If (j = 1) Then
                   Print #1, newMos;
                   Print #1, "',";
             End If
             If (j = 2) Then
                   Print #1, "'";
                   Print #1, Trim(Sheets("mos").Range("C" &
                         rowpos).Value);
                   Print #1, "',";
             End If
             If (j = 3) Then
                   Print #1, "'";
                   Print #1, Trim(Sheets("mos").Range("D" &
                         rowpos).Value);
                   Print #1, "',";
             End If
             If j = 4 Then
                   Print #1, "'";
                   Print #1, "2001";
```

```
                    Print #1, "'";
                End If
                If j = 5 Then
                    k = 0
                    Print #1, ")$rreqset('";
                    Format(Sheets("mos").Range("B" & rowpos).Value,
                    "0000"); "','"; _
                    ; newMos; "','"; Trim(Sheets("mos").Range("C" &
                    rowpos).Value); _
                    ; "','"; Trim(Sheets("mos").Range("D" &
                    rowpos).Value); "') = ";
                    Print #1, Trim(Sheets("mos").Range("E" &
                    rowpos).Value);
                    Print #1, ";";
                End If
        Next j
        Print #1, ' writes a blank line

    newMos = Sheets("mos").Range("A" & rowpos + 1).Value
    If Len(newMos) = 3 Then
        newMos = "0" & newMos
    End If
    tempOc = Left(newMos, 2)
    Ocrt = Right(newMos, 2)
    End If
    newMos = Sheets("mos").Range("A" & rowpos + 1).Value
    If Len(newMos) = 3 Then
        newMos = "0" & newMos
    End If
    tempOc = Left(newMos, 2)
    Ocrt = Right(newMos, 2)
    Next rowpos
    Print #1, ";"
    Print #1,
    Print #1, "* Target Table as of: " + Str(AsOf)
    ' Close before reopening in another mode.
    Close #1
Next occfield
End Sub
```

4. EXCEL MACRO SETBOOT()

SetBoot() takes the "4th and 5th year TOE" worksheet initialization numbers from EAM and loads them into the MTYP initialization variable *A*. SetBoot() reads the numbers in from the worksheet cells and writes them into a text data file. The text data file contains settings for *A.fx*, a fixing variable for MTYP model. *A.fx* numbers are only set for the 2nd year in the time horizon: in this case, it is for 2002. The data is written into a file named A.dat, in the same directory as the workbook that contains SetBoot().

```
Sub SetBoot()
'
' SetBoot Macro
' Macro recorded 2/26/2002 by jcenholm
'
' Keyboard Shortcut: Ctrl+Shift+B
'
Dim InitialArray(200, 2) ' array containing Initial values
Dim AsOf, CurrDir
AsOf = Now
CurrDir = ThisWorkbook.Path

'Load promotion values into PromArray
    For i = 0 To 199
        InitialArray(i, 0) = Sheets("4and5TOE").Range("A" & 9 +
i).Value
        InitialArray(i, 1) = Sheets("4and5TOE").Range("B" & 9 +
i).Value
```

```
        Next i

    ' Open file and write data to it.
    Open CurrDir & "\A.dat" For Output As #1

    ' print initial levels as A.fx fixed variables in GAMS

    For i = 0 To 199
       For j = 0 To 1
         If (j = 0) Then
           Print #1, "A.fx('E3', '";
           Print #1, Trim(InitialArray(i, j));
           Print #1, "','0','1','2002')";
           Print   #1,   "$rreqset('E3','";   Trim(InitialArray(i,   j));
"','0','1')= ";

         Else
           Print #1, Format(InitialArray(i, j), "0000");
           Print #1, ";";
        End If
       Next j
       Print #1, ' writes a blank line
    Next i
    Print #1,
    Print #1, "* Fixed initial Marine Values set: " + Str(AsOf)

    ' Close before reopening in another mode.
```

```
Close #1


End Sub
```

5. EXCEL MACRO SETGAR()

SetGar() takes the fspggar numbers from the manpower planning spreadsheet and creates GAMS-readable data files tailored to occupational fields. The fspggar target numbers are indexed by rank, MOS, and horizon-year.

```
Sub SetGar()
'
' SetGar Macro
' 12/05/01 by Jake Enholm for Marine 30 year plan
' Sets the by Rank Targets for the Model


'
' Assign rank dimension.


Dim TargetArray(295, 9) ' array containing Target values
Dim AsOf, CurrDir
AsOf = Now
CurrDir = ThisWorkbook.Path
For k = 2 To 7
'Load promotion values into PromArray
   If (k = 2) Then
      yearstring = ".(2001*2002)"
   ElseIf (k = 3) Then
```

```
         yearstring = ".2003       "
      ElseIf (k = 4) Then
         yearstring = ".2004       "
      ElseIf (k = 5) Then
         yearstring = ".2005       "
      ElseIf (k = 6) Then
         yearstring = ".2006       "
      Else ' (k = 7) Then
         yearstring = ".(2007*2030)"
      End If


        ‘ read in targets
       For i = 0 To 294
           TargetArray(i,   0)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("A" & 2 + i).Value
           TargetArray(i,   1)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("B" & 2 + i).Value
           TargetArray(i,   2)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("C" & 2 + i).Value
           TargetArray(i,   3)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("D" & 2 + i).Value
           TargetArray(i,   4)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("E" & 2 + i).Value
           TargetArray(i,   5)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("F" & 2 + i).Value
           TargetArray(i,   6)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("G" & 2 + i).Value
           TargetArray(i,   7)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("H" & 2 + i).Value
           TargetArray(i,   8)   =   Sheets("0"   +   Chr(k   +   48)   +
"P").Range("I" & 2 + i).Value
```

```
        Next i


   ' Open file for particular occfield and write data to it.
   Open CurrDir & "\FspgGar0" + Chr(k + 48) + ".dat" For Output As #1


   ' print GAMS fspggar table
   Print #1, "TABLE  fspggar(mos, t, rank)  FSPG rank mos targets"
   Print #1,
   Print #1, "                    " + "ret" + "     " + "E9" + "      "
+ "E8" + "      " + "E7" _
             + "      " + "E6" + "      " + "E5" + "      " + "E4" + "
" + "E3"


   For i = 0 To 294
      For j = 0 To 9
        If (j = 0) Then
          Print #1, ;
          Print #1, Trim(TargetArray(i, j)) + yearstring;
        Else
          Print #1, "    ";
          Print #1, Format(TargetArray(i, j), "0000");
        End If
      Next j
      Print #1, ' writes a blank line
   Next i
   Print #1, ";"
   Print #1,
   Print #1, "* Target Table as of: " + Str(AsOf)
```

```
' Close before reopening in another mode.
Close #1
Next k

End Sub
```

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APPENDIX D. CONTINUATION RATE MOS SUBSTITUTIONS

MOS	DATA USED FROM MOS	REASON	COMMENTS
0613 Construction Wireman (Pvt to Sgt)	2513 Construction Wireman (Pvt to Sgt)	MOS changed	
0614 Unit Level Switch Operator/Maintainer (Pvt to Sgt)	2515 Unit Level Switch Operator/Maintainer (Pvt to Sgt)	MOS changed	
0619 Wire Chief (SSgt to GySgt)	2519 Wire Chief (SSgt to GySgt)	MOS changed	
0624 High frequency Communication Central Operator (Pvt to Sgt)	2534 High frequency Communication Central Operator (Pvt to Sgt)	MOS changed	
0626 Fleet SATCOM Operator (Pvt to Sgt)	2536 Fleet SATCOM Operator (Pvt to Sgt)	MOS changed	
0627 Ground Mobile Forces SATCOM Operator (Pvt to Sgt)	2536 Fleet SATCOM Operator (Pvt to Sgt)	Lack of Data	
0681 Information Security Technician (Sgt to MGySgt)	4067 MOS 4067, Programmer, ADA (Pvt to MGySgt)	New MOS	Lat moves E5-E9
0689 Information Assurance Technician (SSgt to MGySgt)	4067 MOS 4067, Programmer, ADA (Pvt to MGySgt)	New MOS	Lat moves E6-E9
2673,2676 MOS 2673, Korean Cryptologic Linguist (Pvt to GySgt) MOS 2676, Russian Cryptoloqic Linguist (Pvt to GySgt)	2673+2676	Lack of Data	

MOS	DATA USED FROM MOS	REASON	COMMENTS
2844 Ground Communications Organizational Repairer (Pvt to Sgt)	2841 Ground Radio Repairer (Pvt to Sgt)	Lack of Data	2841 is discontinued MOS
2846 Ground Radio Intermediate Repairer (Pvt to Sgt)	2841	Lack of Data	
2862 MOS 2862, Ground Data/Communications Maintenance Technician (GySgt to Sgt)	2861 MOS 2861, Radio Technician (GySgt to Sgt)	Lack of Data	2861 discontinued MOS
2887 Counter Mortar Radar Repairer (Pvt to Sgt)	2831 Multichannel Equipment Repairer (Pvt to Sgt)	Lack of Data	
4099,5993 Data Processing Chief, Electronics Maintenance Chief (MGySgt)	4099+5993 Data Processing Chief, Electronics Maintenance Chief (MGySgt))	Lack of Data	
4612 Combat Lithographer (Pvt to GySgt)	4641 Combat Photographer (Pvt to GySgt)	Lack of Data	
4691 Visual Information Chief (MSgt to MGySgt)	6019 Aircraft Maintenance Chief (MSgt to MGySgt)	Lack of Data	
5526,5528 Musician, Oboe/English Horn (Pvt to GySgt) Musician, Bassoon (Pvt to GySgt)	5526+5528	Lack of Data	
5548, 5565, 5566 Musician, String Bass/Electric Bass (Pvt to GySgt) Musician, Piano (Pvt to GySgt) Musician, Guitar (Pvt to GySgt)	5548+5565+5566	Lack of Data	

MOS	DATA USED FROM MOS	REASON	COMMENTS
6213 Fixed Wing Aircraft Mechanic, EA6 (Pvt to GySgt)	6013 Fixed Wing Aircraft Mechanic, EA6 (Pvt to GySgt)	MOS change	
6223 Fixed Wing Aircraft Power Plants Mechanic, J-52 (Pvt to GySgt)	6022 Fixed Wing Aircraft Power Plants Mechanic, J-52 (Pvt to GySgt)	MOS change	
6222 Fixed Wing Aircraft power Plants Mechanic, Rolls Royce Pegasus (Pvt to GySgt)	6025 Fixed Wing Aircraft power Plants Mechanic, Rolls Royce Pegasus (Pvt to GySgt)	MOS change	
6226 Fixed Wing Aircraft Power Plants Mechanic, T-56 (Pvt to GySgt)	6026 Fixed Wing Aircraft Power Plants Mechanic, T-56 (Pvt to GySgt)	MOS change	
6227 Fixed Wing Aircraft Power Plants Mechanic, F-404 (Pvt to GySgt)	6027 Fixed Wing Aircraft Power Plants Mechanic, F-404 (Pvt to GySgt)	MOS change	
6232 Fixed Wing Aircraft Flight Mechanic, KC-130 (Pvt to Sgt)	6030 Fixed Wing Aircraft Flight Mechanic, KC-130 (Pvt to Sgt)	MOS change	
6253 Fixed Wing Aircraft Airframe Mechanic, EA-6 (Pvt to GySgt)	6053 Fixed Wing Aircraft Airframe Mechanic, EA-6 (Pvt to GySgt)	MOS change	
6252 Fixed Wing Aircraft Airframe Mechanic, AV8 (Pvt to GySgt)	6055 Fixed Wing Aircraft Airframe Mechanic, AV8 (Pvt to GySgt)	MOS change	
6256 Fixed Wing Aircraft Airframe mechanic, KC-130 (Pvt to GySgt)	6056 Fixed Wing Aircraft Airframe mechanic, KC-130 (Pvt to GySgt)	MOS change	

MOS	DATA USED FROM MOS	REASON	COMMENTS
6257 Fixed Wing Aircraft Airframe Mechanic, F/A18 (Pvt to GySgt)	6057 Fixed Wing Aircraft Airframe Mechanic, F/A18 (Pvt to GySgt)	MOS change	
6074 Cryogenics Equipment Operator (Pvt to GySgt)	6073 Aircraft Maintenance Support Equipment Electrician/ Refrigeration Mechanic (Pvt to GySgt)	Lack of Data	
6116 Tiltrotor Mechanic, MV-22 (Pvt to GySgt)	6112 Helicopter Mechanic, CH-46 (Pvt to GySgt)	New MOS	
6156 Tiltrotor Airframe Mechanic, MV-22 (Pvt to GySgt)	6152 Helicopter Airframe Mechanic, CH-46 (Pvt to GySgt)	New MOS	
6176 Tiltrotor Crew Chief, MV-22 (Pvt to GySgt)	6172 Helicopter Crew Chief, CH-46 (Pvt to GySgt)	Lack of Data	
6242 Fixed-Wing Aircraft Flight Engineer, KC-130 (MGySgt to Sgt)	6032 Fixed-Wing Aircraft Flight Engineer, KC-130 (MGySgt to Sgt)	MOS change	
6282,6283,6286,6287 Fixed-Wing Aircraft Safety Equipment Mechanic, AV-8/TAV-8 (Pvt to GySgt) Fixed-Wing Aircraft Safety Equipment Mechanic, EA-6 (Pvt to GySgt) Fixed-Wing Aircraft Safety Equipment Mechanic, KC-130 (Pvt to GySgt) Fixed-Wing Aircraft Safety Equipment Mechanic, F/A-18 (Pvt to GySgt)	6085,6083,6086,6087 Fixed-Wing Aircraft Safety Equipment Mechanic, AV-8/TAV-8 (Pvt to GySgt) Fixed-Wing Aircraft Safety Equipment Mechanic, EA-6 (Pvt to GySgt) Fixed-Wing Aircraft Safety Equipment Mechanic, KC-130 (Pvt to GySgt) Fixed-Wing Aircraft Safety Equipment Mechanic, F/A-18 (Pvt to GySgt)	MOS changes	

MOS	DATA USED FROM MOS	REASON	COMMENTS
6326 Aircraft Communications/Navigation /Electrical/Weapon Systems Technician, V-22 (Pvt to GySgt)	6322 Aircraft Communications/Navigation /Electrical Systems Technician, CH-46 (Pvt to GySgt)	New MOS	
6461 Hybrid Test Set Technician, IMA (Pvt to Sgt)	6465 Hybrid Test Set Technician, IMA (Pvt to Sgt)	MOS change	
6694 Aviation Information Systems (AIS) Specialist (Pvt to MGySgt)	6046 Aircraft Maintenance Administration Specialist (Pvt to MGySgt)	Lack of Data	

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APPENDIX E. MODEL ARCHITECTURE

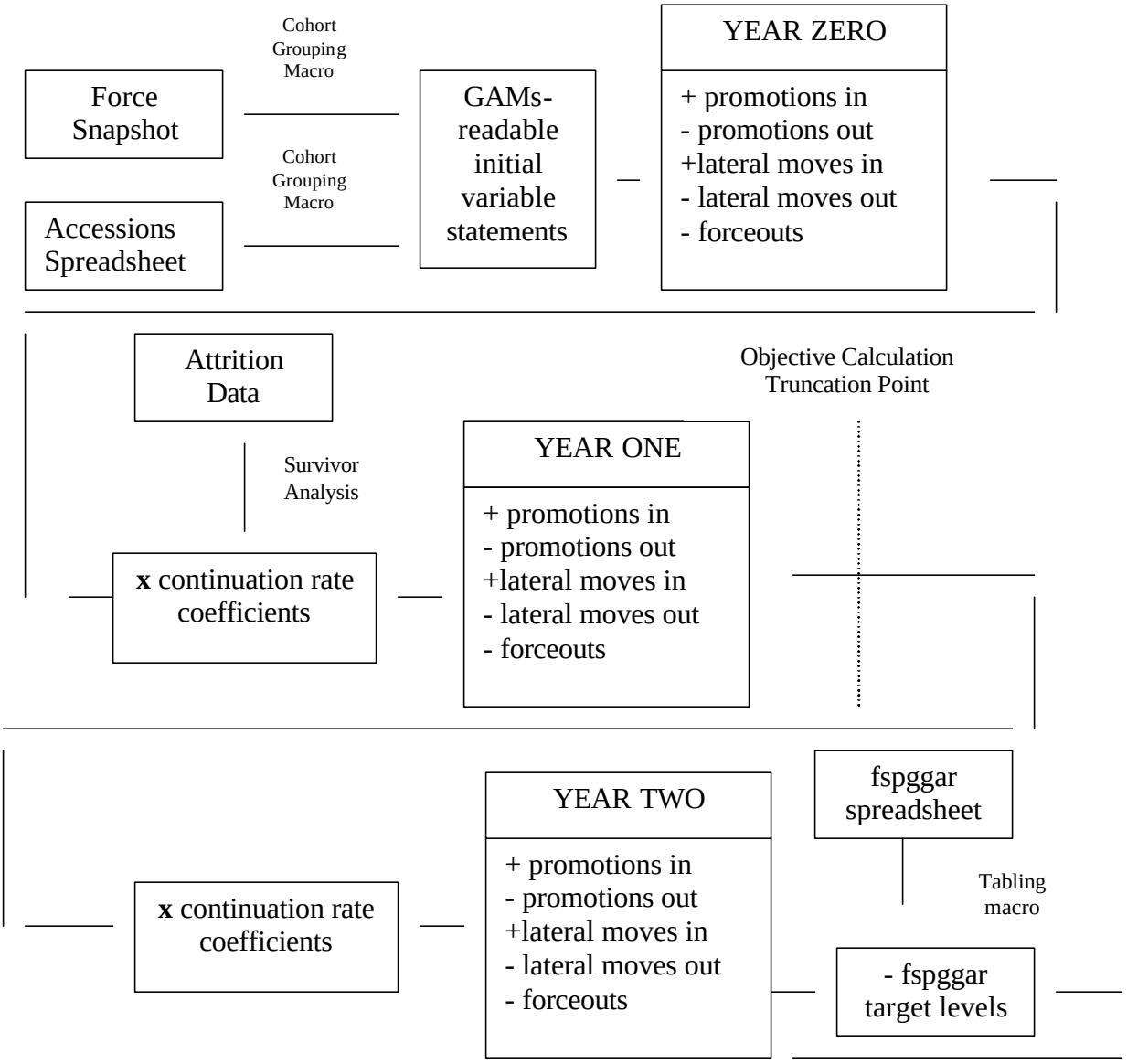

Figure 19. Data flow and Calculation Architecture

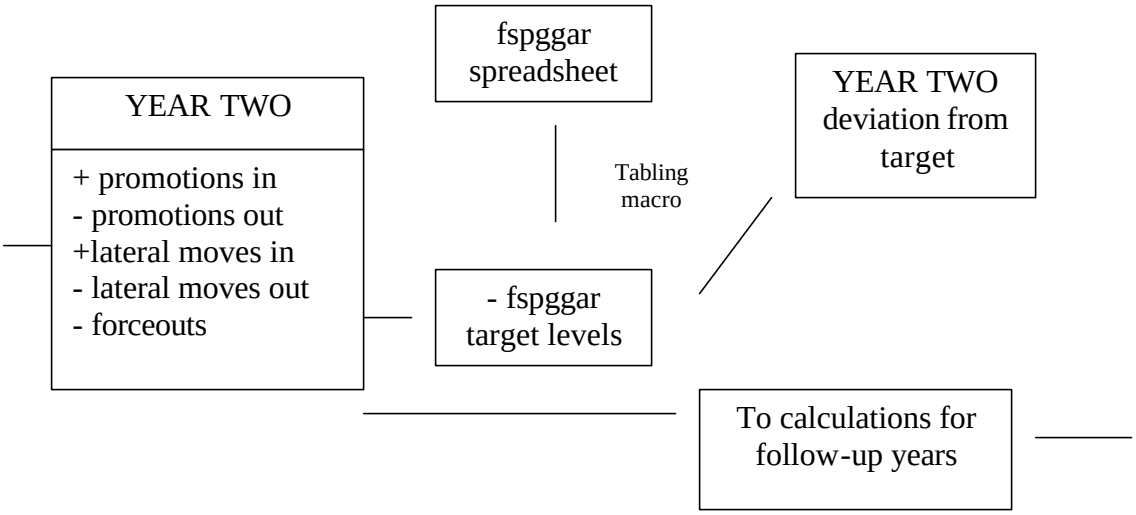

Figure 20. Continuation of Figure 19

LIST OF REFERENCES

Ahuja, R., Magnanti, T., and Orlin, J., 1993, *Network Flows*, Prentice-Hall Inc., New Jersey.

Baumgarten, Peter B., 2000, "Optimization of United States Marine Corps Officer Career Path Selection," M.S. Thesis, Naval Postgraduate School, Monterey, California, September.

Brooke, A., Kendrick D., Meeraus, A., and Raman, R., 1997, *GAMS, Release 2.25, Version 92, Language Guide*, Gams Development Corporation, Washington D.C.

Durso, A. and Donahue, S.F., 1995, "An Analytical Approach to Reshaping the U.S. Army," *Interfaces* v. 25, pp. 109-133.

Elis, H., 1999, "A Decomposition Analysis of First-Term Attrition in the U.S. Military," M.S. Thesis, Naval Postgraduate School, Monterey, California, August.

Grinold, R.C, and Marshall, K.T., 1975a, "Manpower Planning Models III," Technical Report, Naval Postgraduate School, Monterey, California, August.

Grinold, R.C, and Marshall, K.T., 1975b, "Manpower Planning Models IV," Technical Report, Naval Postgraduate School, Monterey, California, October.

Grinold, R.C, and Marshall, K.T., 1975c, "Manpower Planning Models V," Technical Report, Naval Postgraduate School, Monterey, California, November.

Grinold, R.C., 1983, "Model Building Techniques for the Correction of End Effects in Multistage Convex Programs," *Operations Research*, v. 31, pp. 407-431.

Headquarters Marine Corps, Manpower Website: https://osprey.manpower.usmc.mil, Accessed 10 February 2002.

Headquarters Marine Corps, 2000, *Marine Corps Promotion Manual, Volume 2 Enlisted Promotions, MCO P1400.32C*, October.

Headquarters Marine Corps, 1999, *Enlisted Lateral Move Program, MCO 1220.5J*, May.

Headquarters Marine Corps, 2000, *Military Occupational Specialties Manual, MCO P1200.7V*, October.

Headquarters Marine Corps, 1998, *Enlisted Career Force Controls Program, Marine Corps Bulletin 5314*, October.

Høyland, A., and Rausland, M., 1994, *System Reliability Theory*, John Wiley and Sons Inc., New York.

Kablfleisch, J. D. and Prentice, R. L. 1980, *The Statistical Analysis of Failure Time Data.* John Wiley and Sons Inc., New York.

Kaplan, E. L., and Meier, Paul, 1958, "Nonparametric Estimations from Incomplete Observations," *Journal of the American Statistical Association Journal*, v. 53, pp. 457-481.

Litzenberg, W. E., 2001, "An Army Reserve Manpower Planning Model," M.S. Thesis, Naval Postgraduate School, Monterey, California, June.

Nguyen, V.Q., 1997, "Analysis of the U.S. Marine Corps' Steady State Markov Model For Forecasting Annual First Term Enlisted Classification Requirements," M.S. Thesis, Naval Postgraduate School, Monterey, California, March.

North, J.H., and Questor, A.O., 1992, "Determining the Number, and Composition of First Term Reenlistments: The First Term Alignment Plan (FTAP)," CRM 92-85, Center for Naval Analysis, Alexandria, Virginia, October.

Ross, D.L., 2001, *Study Directive For USMC Enlisted Manpower Classification/Retention Model*, Headquarters Marine Corps, Enlisted Manpower Planning Office, Quantico, Virginia, March.

Schneider, D. I., 1995, *An Introduction to Programming Using Visual Basic*, Prentice Hall, New Jersey.

Venables, W. N., and Ripley, B. D., 1999, *Modern Applied Statistics with S-Plus, Third Edition*, Springer-Verlag, New York.

Walker, S.C., 1995, "Evaluating End Effects for Linear and Integer Programs Using Infinite Horizon Linear Programming," Ph. D. Dissertation, Naval Postgraduate School, Monterey, California, March.

Walkenbach, John, 1999, *Microsoft® Excel 2000 Power Programming with VBA*, IDG Books Worldwide, Inc., Foster City, California.

Yamada, W.S., 2000, "An Infinite Horizon Army Manpower Planning Model," M.S. Thesis, Naval Postgraduate School, Monterey, California, June.

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